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MANUAL. ACCORDING TO THE CALCULATION OF WIRES AND CABLES,(U)
APR 80 F F KARPOV, V N KOZLOV
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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

MANUAL

ACCORDING TO THE CALCULATION OF WIRES AND CABLES

by

F. F. Karpov, V. N. Kozlov

FOREIGN TECHNOLOGY DIVISION

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(10) By: F. F. Karpov, V. N. Kozlov

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*<u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

Page 1.

MANUAL.

ACCORDING TO THE CALCULATICN CF WIRES AND CABLES.

3rd Publication revised and supplemented.

F. F. Karpov, V. N. Kozlcv. [deceased].

Page 2.

Manual contains reference tables according to the calculation of electric systems by voltage to 10 kV inclusively according to the conditions of heating, permissible losses of voltage and economic current density. Are given data on questions of the control of voltage and compensation for reactive power in distribution networks.

Manual is designed for the technical-engineering personnel, who works according to the design of industrial and public-service electric systems, and can serve as textbook for the electricians and the electricians, occupied during mounting and operation of electrical networks.

Pages 3-4.

No typing.

Page 5.

Section One

GENERAL INFORMATION.

1-1. The conventional designations and auxiliary tables.

Units measurement.

From 1 January, 1963, operates GOST 9867-61, which establishes the use/application of the international system of the units of SI, fundamental units of which are meter, kilogram (unit of mass), second, ampere, degree Kelvin and candle.

The international system of units must be used as preferable in all regions of science, technology and national economy, and also with the teaching.

Table 1-1 gives most commonly used units measurement.

For the units the measurements, not entering the international system of SI, are given the value of the conversion factors:

1 kW•h=3.6•10⁶ J=3.6 MJ;

1 kg•m=9,80665 J (with the rounding 9.81 J);

1 kcal=4186.8 J (with the rounding 4.190 J);

$$t^{\circ}K = t^{\circ}C + 273,15,$$

where t°K - temperature in the degrees Kelvin;

t°C - temperature in centigrades (Centigrade scale).

Designations mathematical.

> - it is more;

≥ - more or is equal to;

< - it is less;

≤ - less than or equal to;

- - from to;

$\sim$ - approximately;

$\approx$ - is approximately equal to;

∞ - the infinite value;

Σ - arithmetical sum.

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Table 1-1. Units are measurement.

(1) Наименование	(2) Обозначение	(1) Наименование	(2) Обозначение
(3) Меры массы		(4) Джоуль	дж (5)
Грамм (6)	г (7)	Килоджоуль (8)	кдж (9)
Килограмм (10)	кг (11)	Мегаджоуль (12)	Мдж (13)
Тонна (14)	т	*(15) Электрические единицы*	
Меры длины (16)		Ампер (17)	а (18)
		Килоампер (19)	ка (20)
Метр (21)	м	Вольт (22)	в (23)
Миллиметр (24)	мм	Киловольт (26)	кв (27)
Сантиметр (25)	см	Ватт (29)	вт (30)
Километр (28)	км	Киловатт (31)	квт (32)
		Мегаватт (34)	Мвт (35)
(33) Меры поверхности		Вольт-ампер (36)	ва (37)
Квадратный метр (38)	$м^2$	Киловольт-ампер (39)	ква (40)
Квадратный миллиметр (41)	$мм^2$	Мегавольт-ампер (42)	Мва (43)
		Ом (44)	ом (49)
Меры объема (45)		Мегом (46)	Мом (47)
		Вольт-ампер реактивный (48)	вар (50)
Кубический метр (49)	$м^3$	Киловольт-ампер реактивный (52)	квар (53)
Кубический миллиметр (51)	$мм^3$		
Меры времени (54)		Мегавольт-ампер реактивный (55)	Мвар (56)
Секунда (57)	сек (58)	Герц (59)	гц (60)
Минута (61)	мин (62)		
Час (63)	ч (64)	*(65) Меры температуры*	
Меры энергии (66)		(67) Градус стоградусной шкалы	°C
Киловатт-час (69)	(68) квт·ч	Градус Кельвина (70)	°K
Килограммометр (71)	(72) кГ·м		

Key: (1). Designation. (2). Designations. (3). Measures of mass. (4). Joule. (5). J. (6). Grams. (7). g. (8). Kilcjcule. (9). kJ. (10). Kilograms. (11). kg. (12). Megajcule. (13). MJ. (14). Ton. (15). Electrical units. (16). Linear measures. (17). Amperes. (18). A. (19). Kiloamperes. (20). kA. (21). Meter. (22). Volts. (23). in. (24). Millimeter. (25). Centimeter. (26). Kilcvclts. (27). kV. (28).

Kilometer. (29). Watts. (30). w. (31). Kilowatts. (32). kW. (33). Surface measures. (34). Megawatts. (35). MW. (36). Voltamperes. (37). VA. (38). Square meter. (39). Kilcvolt-amperes. (40). kVA. (41). Square millimeter. (42). Megavolt-amperes. (43). MVA. (44). Ohms. (45). Volume measures. (46). Megohms. (47). MΩ. (48). Cubic meter. (49). Voltamperes (reactive/jet.) (50). pitch/var. (51). Cubic millimeter. (52). Kilovars. (53). kilovar. (54). Measures cf time. (55). Megavolt-amperes (reactive/jet.) (56). Mvar. (57). Second. (58). s. (59). Hertz. (60). Hz. (61). Minute. (62). min. (63). Hour. (64). h. (65). Measures of temperature. (66). Measures of energy. (67). Centigrade. (68). Kilowatt-hours. (69). kW•h. (70). Degree Kelvin. (71). Kilogrammeter. (72). kg•m.

Table 1-2. Functions of trigonometric values.

cos φ	sin φ	tg φ	cos φ	sin φ	tg φ
1	0	0	0,92	0,392	0,426
0,99	0,141	0,143	0,91	0,415	0,456
0,98	0,199	0,203	0,90	0,436	0,484
0,97	0,243	0,251	0,89	0,456	0,512
0,96	0,280	0,292	0,88	0,475	0,540
0,95	0,312	0,329	0,87	0,493	0,567
0,94	0,341	0,363	0,86	0,510	0,593
0,93	0,368	0,395	0,85	0,527	0,620
0,84	0,543	0,646	0,69	0,724	1,049
0,83	0,558	0,672	0,68	0,733	1,078
0,82	0,572	0,698	0,67	0,742	1,108
0,81	0,586	0,724	0,66	0,751	1,138
0,80	0,600	0,750	0,65	0,759	1,168
0,79	0,613	0,776	0,64	0,768	1,201
0,78	0,626	0,802	0,63	0,776	1,233
0,77	0,638	0,828	0,62	0,785	1,266
0,76	0,650	0,855	0,61	0,792	1,299
0,75	0,661	0,882	0,60	0,800	1,333
0,74	0,673	0,909	0,55	0,835	1,518
0,73	0,683	0,936	0,50	0,866	1,732
0,72	0,694	0,963	0,45	0,893	1,990
0,71	0,704	0,990	0,40	0,916	2,290
0,70	0,714	1,020	0,35	0,936	2,300

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Table 1-3. Designations conditional graphic for the electrical circuits (GOST 7624-62 with change No 1).

(1) Наименование	(2) Обозначение
(3) Ток постоянный. Напряжение постоянное	—
(4) Ток переменный. Напряжение переменное, Общее обозначение	~
(5) Ток переменный трехфазный 50 *гц*	3 ~ 50 (6) *гц*
(7) Нулевая линия (нейтраль). Допускается нулевую точку обозначать знаком «0»	N
(8) Фазы сети трехфазного тока	*A,B,C*

Key: (1). Designation. (2). Designation. (3). Current (permanent. Voltage constant. (4). Current (variable/alternating. Voltage is the variable/alternating, general designation. (5). Current variable/alternating three-phase 50 Hz. (6). Hz. (7). Zero line (neutral). It is allowed/assumed zero point to designate by sign "0". (8). Phases of network/grid of three-phase current.

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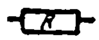
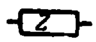
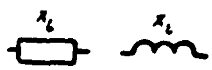
Continuation Table 1-3.

(1) Наименование	(2) Обозначение
(3) Полярность отрицательная	−
(4) Полярность положительная	+
(5) Заземление	⏚
(6) Направление передачи тока, сигнала или потока энергии	⇄
(7) Соединение электрическое металлическое, разъемное и неразъемное. Общее обозначение	●
(8) Примечание. В схемах энергоснабжения для изображения разъемного и неразъемного соединений допускается использовать следующее обозначение:	○
(9) Элемент нагревательный	
(10) Сопротивление для схем эквивалентных и схем замещения:	
(11) а) активное	
(12) б) реактивное	
(13) в) полное	
(14) г) индуктивное	

Key: (1). Designation. (2). Designation. (3). Polarity negative. (4).

Polarity positive. (5). Grounding. (6). Direction of transmission of current, signal or energy flow. (7). Connection electrical metallic, split and nondetachable. General designation. (8). Note. In the diagrams of powering for the image of split and permanent connections it is allowed/assumed to utilize the following designation. (9). Element/cell (heating.) (10). Resistor/resistance for diagrams of equivalent ones and replacement schemes. (11). active. (12). reactive/jet. (13). complete. (14). inductive.

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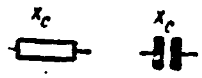
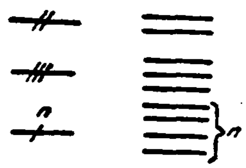
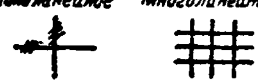
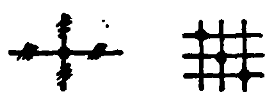
Continuation Table 1-3.

(1) Наименование	(2) Обозначение
д) (3) емкостное	
(4) Линия электрической связи. Общее обозначение	
(7) Цепь из двух, трех и n линий электрической связи	(5) Однолинейное (6) Многолинейное 
(8) Линия электрической связи трехфазной системы с нулевой линией (9) Примечание. Нулевую линию и линии фаз разрешается различать толщинами	
(10) Линии электрической связи пересекающиеся, электрически не соединенные	(5) Однолинейное (6) Многолинейное 
(11) Линии электрической связи пересекающиеся, электрически соединенные	
Ответвление (12) одной линии электрической связи	

Key: (1). Designation. (2). Designation. (3). capacitive. (4). Line

of electric coupling. General designation. (5). Unilinear. (6). Multilinear. (7). Circuit of two, three and n of lines of electric coupling. (8). Line of electric coupling of three-phase system with zero line. (9). Note. Zero line and lines of phases it is permitted to distinguish by thicknesses. (10). Lines of electric coupling which intersect, electrically not connected. (11). Lines of electric coupling which intersect, electrically connected. (12). Branching of one line of electric coupling.

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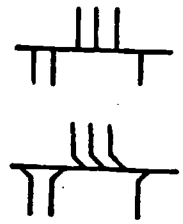
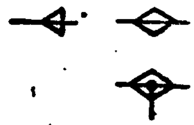
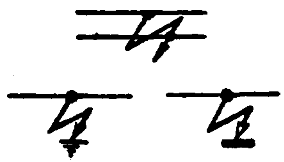
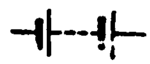
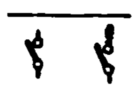
Continuation Table 1-3.

(1) Наименование	(2) Обозначение
(3) Слияние и разветвление линий электрической связи (4) Примечание. Допускается изображать слияние и разветвление линий электрической связи под углом 45°	
(5) Муфты кабельные: концевая, соединительная, для одного ответвления	
(6) Повреждение изоляции: между линиями электрической связи, на землю, на корпус	
(7) Машина вращающаяся. Общее обозначение	
(8) Трансформатор. Общее обозначение	
(9) Батарея из гальванических или аккумуляторных элементов	
(10) Предохранитель плавкий. Общее обозначение	
(11) Выключатели: (12) однополюсный (13) четырехполюсный	

Key: (1). Designation. (2). Designation. (3). Merging/coalescence and branching off of lines of electric coupling. (4). Note. It is allowed/assumed to depict merging/coalescence and branching off of the lines of electric coupling at angle of 45°. (5). Clutches cable: end, coupling, for one branching. (6). Damage to insulation: between lines of electric coupling, to the earth, to housing. (7). Machine rotating. General designation. (8). Transformer. General designation. (9). Battery from galvanic or storage cells. (10). Safety device/fuse (fusible) General designation. (11). Switches. (12). single-pole. (13). four-terminal.

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Continuation Table 1-3.

(1) Наименование	(2) Обозначение
(3) Переключатель на одно направление (однополюсный):	
(4) а) на два положения	
(5) б) на три положения (третье положение нейтральное)	
(6) Разъединитель	
(7) Выключатель автоматический. Общее обозначение	
(8) Выключатель высокого напряжения трехполюсный	
(9) Примечание. В схемах электроснабжения допускается высоковольтный выключатель изображать, как указано	
(10) Обмотки реле, контактора и магнитного пускателя. Допускается применять следующие обозначения:	
(11) Обмотка реле токовая последовательная	
(12) Обмотка реле напряжения параллельная	
(13) Обмотки контактора и магнитного пускателя	

Key: (1). Designation. (2). Designation. (3). Switch to one direction (single-pole). (4). to two positions. (5). to three positions (third position neutral). (6). Disconnector. (7). Switch (automatic) General designation. (8). High-voltage switch tripolar. (9). Note. In the diagrams of power supply it is allowed/assumed high-voltage switch to depict, as it is shown. (10). Windings by relay, contactor and magnetic starter. It is allowed/assumed to apply the following designations. (11). Winding by relay current consecutive. (12). Winding by voltage relay parallel. (13). Windings of contactor and magnetic starter.

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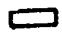
Table 1-4. Designaticns tne conditional graphic of electrical equipment and wirings cn tne plans/layouts (GCST 7621-55).

(1) Наименование	(2) Обозначение
(3) Электродвигатель асинхронный	
(4) Электродвигатель синхронный	
(5) Несколько электродвигателей, составляющих многодвигательный привод	
(6) Трансформатор	
(7) Подстанция трансформаторная	
(8) Щит, пульт, шкаф управления	
(9) Щит, сборка распределительная	
(10) Шкаф распределительный (силовой и освещения)	
(11) Щиток групповой рабочего освещения	
(12) Щиток групповой аварийного освещения	

Key: (1). Designation. (2). Designation. (3). Electric motor (asynchronous.) (4). Electric motor (synchronous.) (5). Several electric motors, which compose co-ordinated drive. (6). Transformer. (7). Substation transformer. (8). Panel, panel, cabinet of control. (9). Panel, assembly distributive. (10). Cabinet distributive (power and illumination). (11). Panel of group of working illumination. (12). Panel of group of emergency light.

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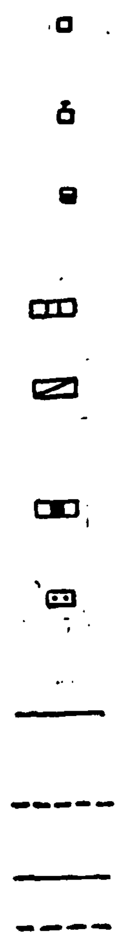
Continuation table 1-4.

(1) Наименование	(2) Обозначение
(3) Пускатель	
(4) Реостат	
(5) Ящик с автоматом	
(6) Ящик с рубильником	
(7) Ящик с предохранителями	
(8) Ящик с рубильником и предохранителями	
(9) Кнопка управления	
(10) Линия силовой распределительной сети переменного тока напряжением до 660 в* включительно	
(11) Линия силовой распределительной сети переменного тока напряжением свыше 660 в**	
(12) Линия сети рабочего освещения:	
(13) а) для чертежей только электроосвещения	
(14) б) для чертежей с совмещенными сетями (силовой и осветительной)	



Key: (1). Designation. (2). Designation. (3). Starter. (4). Rheostat. (5). Cabinet with automatic machine. (6). Cabinet with knife switch.

(7). Cabinet with safety devices/fuses. (8). Cabinet with knife switch and safety devices/fuses. (9). Control knob. (10). Line of power distribution network of alternating current by voltage to 660 in [1] inclusively.

FOOTNOTE [1]. According to GOST 7621-55 to 500V. ENDFOOTNOTE.

(11). Line of power distribution network of alternating current by voltage is more than 660 in [2].

FOOTNOTE [2]. According to GOST 7621-55 it is more than 500V. ENDFOOTNOTE.

(12). Line of network/grid of working illumination. (13). for drawings only of electric lighting. (14). for drawings with combined networks/grids (power and lighting).

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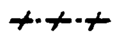
Continuation table 1-4.

(1) Наименование	(2) Обозначение
(3) Линия сети аварийного освещения:	
(4) а) для чертежей только электроосвещения	
(5) б) для чертежей с совмещенными сетями (силовой и осветительной)	
(6) Линия сети напряжением 36 *в* и ниже	
(7) Линия заземления	
(8) Линия уходит вниз	
(9) Линия приходит сверху	
(10) Линия разветвляется и уходит вверх и вниз	
(11) Три одножильных провода марки АПР сечением 10 *мм*², прокладываемых на изоляторах (пример)	АПР 3(1×10)И
(12) Два четырехжильных кабеля марки ААГ сечением 3×50+1×25 *мм*², прокладываемых каждый в отдельной стальной трубе диаметром 1½" (пример)	ААГ 2(3×50+1×25) 2Т 1½"

Key: (1). Designation. (2). Designation. (3). Line of network/grid of emergency light. (4). for drawings only of electric lighting. (5). for drawings with combined networks/grids (power and lighting). (6). Line of network/grid by voltage 36V is below. (7). Line of grounding. (8). Line goes down. (9). Line comes on top. (10). Line branches and

departs upward and downward. (11). Three wires of model APR by section 10 mm^2, run on insulators (example). (12). Two four-wire cables of brand AAG with section 3x50+1x25 mm^2, run each in separate steel tube with a diameter of $1^1/_2$" (example).

1-2. Fundamental information from electrical engineering.

The current strength is determined according to the law of the ohm:

for the direct-current circuit

$$I = \frac{U}{R}, \text{ A}; \quad (1\text{-}1)$$

for the alternating current circuit

$$I = \frac{U}{Z}, \text{ A}, \quad (1\text{-}2)$$

where U - the voltage, V;

R - ohmic resistance, ohm;

Z - impedance, ohm.

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Ohmic resistance depends on material and geometric dimensions of the conductor:

$$R=\rho\frac{l}{F};\ \text{ohm,}\quad (1\text{-}3)$$

where l - length of conductor, m;

F - cross section, the mm²;

ρ - specific resistor/resistance, $\Omega\cdot mm^2/m$.

Impedance of alternating current circuit is defined as vector sum active R and inductive of the X resistors/resistances:

$$Z=\sqrt{R^2+X^2},\ \text{ohm.}\quad (1\text{-}4)$$

Fundamental principles in the system of the three-phase alternating current:

with the connection into the star

$$U_\phi=\frac{U_л}{\sqrt{3}},\ ^{(1)}в;$$

$$I_\phi=I_л,\ ^{(2)}а;$$

Key: (1). V. (2). A.

with the connection into the triangle

$$U_{\Phi}=U_{\text{л}},\ \overset{(1)}{\text{в}};$$

$$I_{\Phi}=\frac{I_{\text{л}}}{\sqrt{3}},\ \overset{(2)}{\text{а}}.$$

Key: (1). V. (2). A.

where indices "f" and "l" correspond to the phase and linear (interphase) values of value.

Power of direct-current circuit

$$P=UI=I^2R,\ \text{W}. \quad (1\text{-}5)$$

The power of the single-phase alternating current:

is active

$$P=UI\cos\varphi,\ \text{W}; \quad (1\text{-}6)$$

reactive/jet

$$Q=UI\sin\varphi,\ \text{pitch/var}. \quad (1\text{-}7)$$

The power of the three-phase alternating current:

is active

$$P = \sqrt{3}\, UI \cos\varphi, \text{ w}; \quad (1\text{-}8)$$

reactive/jet

$$Q = \sqrt{3}\, UI \sin\varphi, \text{ pitch/var.} \quad (1\text{-}9)$$

The total power of the three-phase alternating current

$$S = \sqrt{3}\, UI = \sqrt{P^2 + Q^2}, \text{ VA.} \quad (1\text{-}10)$$

Factor of power (cos φ) is called the ratio of active power (watt, kilowatt) to the total power (voltampere, kilovolt-ampere). Factor of the power in general always less than the unit. Only with the purely resistive load (incandescent lighting, electrical heating installations) it is equal to unit.

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1-3. Definitions.

According to the determination of the rules of the device/equipment of the electrical devices (PUE) of line, the

employees for transmission and electrical power distribution, are subdivided into aerial lines, cable lines, electric wirings and conductors.

Aerial line (VL) is called device/equipment for transmission and electrical power distribution according to the wires, arranged/located on the open air and fixed with the aid of the insulators and the armature to supports or brackets of engineering facilities (bridges, overpasses, etc.). Aerial lines are subdivided into the line by the voltage of above 1 kV and line by voltage to 1 kV.

Cable line is called the line for the electric transmission, which consists of one or several cables with coupling and terminals (seals) and fasteners. Cable lines run underground in the trenches, under water, in the special installations (blocks, mines/shafts, etc.), and also in the open air both inside and outdoors.

Electric wiring is called the totality of wires and cables with the relating to them attachments, the supporting and shielding constructions/designs. The electric wirings include the power and lighting lines of direct and alternating current by voltage of up to 1000V, laid within the buildings and the installations, on their external walls, on the territories of courts and homestead sections,

made by insulated wires, and alsc by unarmored india-rubber cables (for example, brands ASбG, AVлG, etc.) of fine/small sections (tc 16 mm^2 inclusively).

Electric wirings using the method of fulfillment are divided into the following fcrms:

1. Open, laid over the surface of walls and ceilings, on the farms/trusses, etc. Open wiring can be staticnary, movable and movable.

2. Concealed/latert, continued in structural elements/cells of buildings (walls, floors/sexes and overlaps).

Conductors are called devices/equipment for the intrashop transmission and electrical pcwer distributicn of the industrial enterprises of ferrous and ncnferrcus metallurgy, chemical and other energy productions. Conductcrs ccnsist of bare or insulated busbars, laid in the ducts, the closed galleries cr the tunnels, and it is also cpened on the supporting structures. Conductcrs are applied with the voltages bcth cf up tc 1000V and above 1000V.

1-4. Nominal voltages.

Table 1-5-1-8 gives the nominal voltages of electrical networks, transformers, sources and receivers of electrical energy to 10 kV inclusively according to GOST 721-62, introduced on 1 January, 1963.

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Table 1-5. Nominal voltages of electrical networks, sources and receivers of electrical energy of up to 100V.

(1) Постоянный ток, в	(2) Трехфазный ток (междуфазное напряжение), в	(3) Однофазный ток, в
6	—	—
12	—	12
24	—	24
36	36	36
48	—	—
60	—	—

Key: (1). Direct current, V. (2). Three-phase current (interphase voltage), V. (3). Single-phase current, V.

Table 1-6. The nominal voltages of electrical networks, sources and receivers of electrical energy are more than 100 of up to 1000V (direct current), V.

(1) Сети и приемники электрической энергии	(2) Источник питания
110	115
220	230
440	460

Key: (1). Networks/grids and receivers of electrical energy. (2). Power supply.

Table 1-7. Nominal voltages of electrical networks, sources and receivers of the electrical energy (alternating current), V.

(1) Сети и приемники электрической энергии			(2) Генераторы трехфазного тока (междуфазное напряжение)	(3) Трансформаторы			
(4) трехфазного тока		(7) однофазного тока		(4) трехфазного тока		(7) однофазного тока	
(5) междуфазное напряжение	(6) фазное напряжение			(8) первичные обмотки	(9) вторичные обмотки	(8) первичные обмотки	(9) вторичные обмотки
—	127	127	—	—	—	127	133
220	220	220	230	220	230	220	230
380	380	380	400	380	400	380	—
660	—	—	690	660	690	660	—

Note. For existing electrical networks with the nominal voltage 500V must be manufactured the electrical equipment to this voltage.

Key: (1). Networks/grids and receivers of electrical energy. (2). Threephase generators (interphase voltage). (3). Transformers. (4). three-phase current. (5). interphase voltage. (6). phase voltage. (7). single-phase current. (8). primary windings. (9). secondary windings.

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Table 1-8. The nominal interphase voltages of three-phase current are more than 1000V electrical networks, generators, transformers and receivers electrical energy, and also their greatest operating voltages, long permitted according to the working conditions of insulation, kV.

(1) Сети и приемники электрической энергии	(2) Генераторы	(3) Трансформаторы (4) первичные обмотки	(5) вторичные обмотки	(6) Наибольшее рабочее напряжение
3	3.15	(7) 3 и 3.15	3.15 и 3.3	3.5
6	6.3	6 и 6.3	6.3 и 6.6	6.9
10	10.5	10 и 10.5	10.5 и 11	11.5

Notes: 1. Table 4 of GOST 721-62 is given incompletely, since present manual is limited to electrical networks to the nominal voltage to 10 kV.

2. Nominal voltages of primary windings of transformers 3.15; 6.3 and 10.5 kV relate to transformers, connected directly to busbars of generator voltage of electrical stations or outputs of generators.

3. With the presence in winding of transformer of several branchings indicated in Table 1-8 nominal voltages relate to its fundamental branching. For the fundamental branching one should accept: with the odd number of branchings - average/mean branching,

with even number of branchings - branching with the nearest large voltage with respect to the medium voltage of the range of control.

Key: (1). Networks/grids and receivers of electrical energy. (2). Generators. (3). Transformers. (4). primary windings. (5). secondary windings. (6). Great is working voltage. (7). and.

1-5. Fundamental requirements for electrical networks.

Electrical networks must satisfy the following fundamental conditions:

1. To be safe for life and health of person and not to create the threat of the onset of fire or blast. One of the necessary conditions without the danger in electrical network is the correct selection of the section of wires and cables according to the condition of their heating operating current, and in certain cases and overload protection. For the cables the safety is guaranteed also by their thermal resistance during the short circuit (see Section 4, 6 and 7).

For the safe operation of network/grid is necessary also the correct selection of brand and method of the wiring and cables in accordance with the characteristic of the environment.

2. To possess sufficient reliability, i.e., not to be reason for breaks in feed by electric power or connected users. One of the conditions of guaranteeing the reliability of electric system is sufficient mechanical strength of wires, cables and conductors. Calculations for the mechanical strength of the wires of air electric power lines with the effect of the stress of wires themselves, ice-covered surface, wind, etc. do not enter into the goal of present manual.

Tables 1-10 and 1-11 give the smallest permissible on the mechanical strength sections of wires in depending on the method of separator and line voltage.

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Table 1-9. Selection of the voltage of distribution networks.

(1) Номинальное напряжение сети, в	(2) Область применения
	(3) *1. Напряжение выше 1 000 в*
3 000	(4) В качестве основного напряжения распределительной сети находит редкое применение. Может быть применено лишь после надлежащего технико-экономического обоснования на предприятии с относительно небольшой потребляемой мощностью и при значительном числе электродвигателей мощностью 75—200 *квт*
6 000	(5) Целесообразно применять на промпредприятиях при наличии значительного числа электроприемников на 6 *кв*. При реконструкции существующих городских сетей 6 *кв* применяется при условии обоснования технико-экономическим расчетом
10 000	(6) Рекомендуется к широкому применению в городах и сельских районах, а также на промпредприятиях при отсутствии большого числа электроприемников, которые могут питаться непосредственно от сети 6 *кв*
	(7) *2. Напряжение до 1 000 в*
660	(8) Рекомендуется к широкому применению в угольной, горнорудной, химической и нефтяной отраслях промышленности. Допускается без ограничения для всех отраслей промышленности во всех случаях, когда это экономически целесообразно
380/220	(9) Является основным напряжением городских электросетей. Применяется для питания силовых и осветительных электроприемников промышленных предприятий по четырехпроводной системе от общих трансформаторов
(10) 500 и 220 (для силовых электроприемников)	(11) Может быть применено лишь на реконструируемых или расширяемых предприятиях с большим удельным весом сохраняемых установок 220 или 500 *в*
(12) 220/127 (для осветительных сетей)	(13) Может быть допущено после технико-экономического обоснования на реконструируемых или расширяемых предприятиях с большим удельным весом сохраняемых установок 220/127 *в*
36	(14) Для сети местного и ремонтного освещения в помещениях с повышенной опасностью
12	(15) Для сети местного и ремонтного освещения в котельных и других особо опасных помещениях
12, 24, 36, 48, 60, 110, 127, 220	(16) Для питания цепей управления, сигнализации и автоматизации технологических процессов

Key: (1). Nominal line voltage, V. (2). Field of application. (3).

Voltage is above 1000V. (4). As fundamental voltage of distribution network is found rare use. Can be used only after the proper technical-economic substantiation in the enterprise with the relatively low required power and with a considerable number of electric motors in power 75-200 kW. (5). It is expedient to apply on industrial enterprises in presence of considerable number of electrical receivers on 6 kV. During the reconstruction of the existing urban networks/grids 6 kV it is applied under the condition of substantiation by the technical-economic calculation. (6). It is recommended to wide application in cities and rural areas, and also on industrial enterprises in the absence of large number of electrical receivers which can be supplied directly from network/grid 6 kV. (7). Voltage of up to 1000V. (8). It is recommended to wide application in carbon, mining, chemical and petroleum branches of industry. It is allowed/assumed without the limitation for all branches of industry in all cases when this is economically expedient. (9). It is fundamental voltage of urban electric systems. It is applied for the feed of the power and lighting electrical receivers of industrial enterprises for four-wire system from the general/common/total transformers. (10). 500 and 220 (for power electrical receivers). (11). It can be used only in reconstructed or expansible enterprises with a large specific gravity/weight of retained installations of 220 or 500V. (12). (for lighting systems). (13). It can be allowed after technical-economic substantiation in

reconstructed or expansit : enterprises with large specific gravity/weight of retained installations 220/127V. (14). For network/grid of local and repair illumination in locations with increased danger. (15). For network/grid of local and repair illumination in boiler and other especially dangerous locations. (16). For feed of control circuits, signaling and automation of technological processes.

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Table 1-10. Smallest permissible sections of wires and cables in the electric wirings according to the condition of mechanical strength.

(1) Характеристика провода и условий прокладки	(2) Наименьшее сечение, мм²	
	(3) медь	(4) алюминий
(5) Изолированные гибкие провода внутри и снаружи осветительных арматур:		
(6) внутри зданий	0,5	—
(7) вне зданий	1	—
(8) Шнуры в общей оболочке и провода шланговые для присоединения переносных бытовых электроприемников	0,75	—
(9) Кабели и провода шланговые для присоединения переносных электроприемников в промышленных установках	1,5	—
(10) Кабели шланговые для передвижных электроприемников	2,5	—
(11) Скрученные двухжильные провода с многопроволочными жилами для стационарной прокладки на роликах	1	—
(12) Незащищенные изолированные провода для стационарной прокладки внутри помещений:		
(13) на роликах и клицах	1	2,5
(14) на изоляторах	1,5	4
(15) Незащищенные изолированные провода в наружных электропроводках:		
(16) по стенам, конструкциям или опорам на изоляторах	2,5	4
(17) под навесами на роликах	1,5	2,5
(18) Незащищенные изолированные провода и кабели в трубах и металлических рукавах	1	2,5
(19) Кабели и защищенные изолированные провода для стационарной прокладки	1	2,5
(20) Провода внутридомовой сети:		
(21) 1. Групповые линии сети освещения при отсутствии штепсельных розеток	1	2,5
(22) 2. Групповые линии сети освещения со штепсельными розетками и штепсельные линии	1,5	2,5
(23) 3. Вводы в квартиры, к потребителям, расчетным счетчикам	2,5	4
(24) 4. Стояки в жилых зданиях для питания квартир	4	6
(25) Неизолированные провода в зданиях	2,5	4
(26) Неизолированные защищенные от коррозии провода в зданиях	1,5	2,5
(27) Неизолированные провода в наружных проводках	4	10
(28) Изолированные провода и кабели при прокладке во взрывоопасных помещениях в стальных трубах:		
(29) осветительные сети	1,5	2,5
(30) силовые сети	2,5	4

Key: (1). Characteristic of wire and conditions of separator. (2). Smallest section, mm². (3). copper. (4). aluminum. (5). Isolated/insulated patch cords within and outside fittings. (6). within buildings. (7). out of buildings. (8). Cables in general/common/total shell and wire hose for connection of movable everyday electrical receivers. (9). Cables and wires hose for connection of movable electrical receivers in industrial installations. (10). Cables hose for movable electrical receivers. (11). Twisted twin conductors with stranded veins/strands for stationary separator on rollers. (12). Unprotected insulated wires for stationary separator indoors. (13). on rollers and cleats. (14). on insulators. (15). Unshielded insulated wires in external electric wirings. (16). on walls, constructions/designs or supports on insulators. (17). under sheds on rollers. (18). Unprotected insulated wires and pipe cables and metallic hoses/pipes. (19). Cables and shielded insulated wires for stationary separator. (20). Wires of intra-house network/grid. (21). 1. Group lines of network/grid of illumination in the absence of plug sockets. (22). 2. Group lines of network/grid of illumination with plug sockets and plug lines. (23). 3. Introductions/inputs into apartments, to users, calculated counters. (24). 4. Risers in habitable buildings for feed of apartments. (25). Uninsulated wires in buildings. (26). Uninsulated shielded from corrosion wires in buildings. (27). Uninsulated wires in external wirings. (28). Insulated wires and cables with separator in dangerously explosive locations in steel tubes. (29). lighting systems. (30). power networks/grids.

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Table 1-11. Smallest sections of wires and cables of aerial lines, permitted according to the condition of mechanical strength, mm² (or diameters, mm).

(1) Характеристика линий	(2) Конструкция и материал проводов и тросов				
	(3) Алюминиевые, мм²	(4) Сталеалюминиевые, мм²	(5) Биметаллические (сталеалюминиевые), мм²	(6) Стальные: (7) многопроволочные, мм²	(8) однопроволочные (диаметр), мм
(9) *Воздушные линии 1—10 кв:*					
(10) 1. Ненаселенная местность	25	16	—	25	—
(11) 2. Населенная местность	35	25	—	25	—
(12) 3. Пересечения:					
(13) А. Рек, каналов, озер и т. п.:					
судоходных	70	25	—	25	—
несудоходных	35	25	—	25	—
(14) Б. Линий связи и сигнализации	70	25	—	*	—
(15) В. Железных дорог, наземных трубопроводов и канатных дорог	70	35	—	*	—
(16) Г. Автомобильных дорог категории I—IV, трамвайных и троллейбусных линий	35	25	—	25	—
(17) Д. Автомобильных дорог категории V	25	16	—	25	—
(18) Е. Воздушных линий до 10 кв	35	25	—	25	—
(19) 4. Воздушные линии до 1 000 в	16	10	10**	25	4**
(20) 5. Ответвления от воздушных линий к вводам в здания	16	—	4	—	3

Key: (1). Characteristic of lines. (2). Construction/design and material of wires and cables. (3). Aluminum, mm². (4). Steel-aluminum, mm². (5). Composite (steel-aluminum), mm². (6). Steel. (7). stranded, mm². (8). single-wire (diameter), mm. (9). Aerial lines 1-10 kV. (10). 1. Unpopulated locality. (11). 2. Populated locality. (12). 3. Intersections. (13). A. Rivers,

channels, lakes and the like: navigable; unnavigable. (14). B. Lines of communications and signaling. (15). C. Iron ways, ground-based conduits/manifolds and cableways. (16). D. Highways of category of I-IV, tram and trolley-bus lines. (17). E. Highways of category V. (18). F. Aerial lines to 10 kV. (19). 4. Aerial lines to 10 kV. (20). 5. Branchings from aerial lines to entrances.

FOOTNOTE [1]. Is not allowed/assumed the use/application of steel wires, with exception of the lightning arresters.

[2]. Is not allowed/assumed use/application of single-wire wires in diameter of more than 6.5 mm of composite ones and 5 mm of steel ones. ENDFOOTNOTE.

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3. To transmit electric power to users with minimum deviations of voltage from nominal. This is achieved by the calculation of network/grid to the loss of the voltage (see Section 5) and by the selection of the means of regulating voltage during the design of the network/grid (see Section 11), and also by the correct use of these means during the operation.

4. To provide smallest expenditures for operation and construction of electric system upon reaching of conditions, presented in paragraphs 1-3 (see 38-10).

Section Two

BRIEF INFORMATION ABCUT THE CCNSTRUCTION OF WIRES AND CABLES AND THE CONDITIONS OF THEIR SEEAEATCE.

2-1. Wires not insulated.

Wires not insulatea are applied in air electrical networks for transmission and distributing electrical energy. The uninsulated wires run in the open air, attaching to the supports of aerial lines cr the brackets of engineering facilities with the aid of the reinforcement and the insulatcrs.

The primary constructions cf the uninsulated wires they are:

1) single-wire and stranded wires of one metal (copper, aluminum cr steel);

2) the stranded steel-aluminum wires, which have steel core and aluminum shell;

3) single-wire and stranded steel-aluminum wires of the composite wire.

Wires bronze, steel-bronze, composite steel-bronze non-current.

Widest use in aerial networks by voltage to 10 kV inclusively received aluminum wires (Fig. 2-1). Steel wires as a result of their poor conductivity are applied only for the lightly loaded networks/grids in the rural areas.

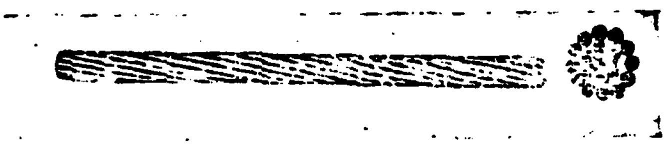

Fig. 2-1. Wire the uninsulated aluminum of brand A.

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Table 2-1. Uninsulated wires.

(1) Марка	(2) Наименование провода	(3) Диапазон сечений, $мм^2$	(4) Область применения
М	(5) Медный	4—400	(6) Для воздушных сетей и линий электропередачи
А	(7) Алюминиевый	16—600	(8) Для воздушных сетей и линий электропередачи до 10 *кв*
АС	(9) Сталеалюминиевый	10—400	(10) То же, когда требуется повышенная механическая прочность проводов (для больших пролетов между точками крепления и для сетей в районах с тяжелыми атмосферными условиями)
АК	(11) Алюминиевый коррозионностойкий	16—600	(12) Для воздушных сетей и линий электропередачи до 10 *кв* для промышленных и морских прибрежных районов, где наблюдается ускоренная коррозия проводов
АСК	(13) Сталеалюминиевый коррозионностойкий	10—400	(14) То же, когда требуется повышенная механическая прочность проводов
БА	(15) Биметаллический сталеалюминиевый	4—500	(16) Провода в диапазоне сечений 4—35 $мм^2$ предназначаются для электрификации сельского хозяйства и для ответвлений от воздушных линий к вводам в здания. *Провода больших* сечений применяются для сооружения больших переходов через реки и другие препятствия
ПСО	(17) Стальной однопроволочный	⌀ 3; 3,5; 4; 5 *мм*	(18) Для воздушных сетей с небольшими нагрузками
ПС	(19) Стальной многопроволочный	25—70	(20) То же

Key: (1). Brand. (2). Designation of wire. (3). Range of sections, mm². (4). Field of application. (5). Copper. (6). For aerial networks and electric power lines. (7). Aluminum. (8). For aerial networks and electric power lines to 10 kV. (9). Steel-aluminum. (10). Then, when is required increased mechanical strength of wires (for large flights/spans between attachment points and for networks/grids in areas with severe atmospheric conditions). (11). Aluminum corrosion-resistant. (12). For aerial networks and electric power

lines to 10 kV for industrial and marine coastal areas where is observed accelerated corrosion of wires. (13). Steel-aluminum corrosion-resistant. (14). Then, when is required increased mechanical strength of wires. (15). Composite steel-aluminum. (16). Wires in the range of sections 4-35 mm² are intended for electrification of agriculture and for branchings from aerial lines to entrances. Heavy guage wires are applied for the construction of large transitions/junctions through the rivers and other obstructions. (17). Steel single-wire. (18). For aerial networks with light loads. (19). Steel stranded. (20). Then.

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For the large flights/spans are applied the steel-aluminum wires (Fig. 2-2), in which steel core serves for amplifying the mechanical strength and aluminum shell is the conducting part of the wire.

Wires aluminum and steel-aluminum are made according to GOST 839-59, and steel - according to GOST 5800-51 and 8053-56.

Brands, ranges of sections and field of application of the uninsulated wires in the networks/grids to the nominal voltage to 10 kV are shown in Table 2-1.

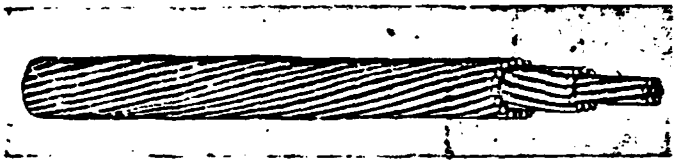

Fig. 2-2. Wire the uninsulated steel-aluminum of brand AS.

Table 2-2. Diameters, weights and construction lengths of the aluminum uninsulated wires.

(1) Номинальное сечение, $мм^2$	(2) Диаметр, мм	(3) Вес 1 км провода, кг	(4) Строительная длина, м
16	5,1	44	4 500
25	6,4	68	4 000
35	7,5	95	4 000
50	9,0	136	3 500
70	10,7	191	2 500
95	12,4	257	2 000
120	14,0	322	1 500
150	15,8	407	1 250
185	17,5	503	1 000
240	20,0	656	1 000
300	22,4	817	1 000
400	25,8	1 087	800
500	29,1	1 376	600
600	32,0	1 658	500

Key: (1). Nominal section, mm^2. (2). Diameter, mm. (3). Weight 1 km of wire, kg. (4). Structural length, m.

2-2. Wires and cords adjusting isolated/insulated.

Adjusting insulated wires and cords serve for distributing

electrical energy in the power and lighting plants with their motionless separator indoors. Insulated wires are applied also for the separator in the open air with the input unit into the buildings and with the wiring on the external walls of building on the insulators.

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Black cables and cords serve also for the feed of electric motors and different industrial and everyday movable electrical receivers.

On the voltage of wire are manufactured to 220, 380, 500, 2000 and 3000 V of alternating current, and cords - on 220 V. According to a number of current-conducting veins/strands of wire are released one-, two-, three-, four-and multiple ones, and the cords - by predominantly twin-cored (Fig. 2-3).

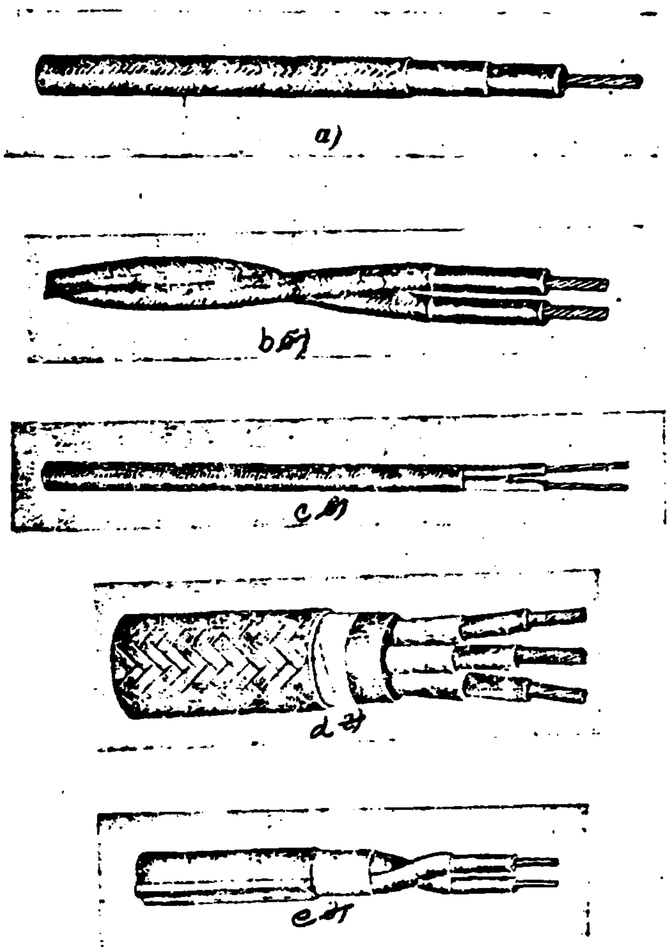

Fig. 2-3. Construction/design of wires and cords. a) PRG; b) ShR; c) DPRG; d) PRShP; e) TPRF and AIPEF.

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Table 2-3. Brands of wires and cords with rubber and polychlorovinyl insulation.

(1) Марка	(2) Наименование проводов и шнуров	(3) ГОСТ или ВТУ
	(4) *1. Установочные провода и шнуры с резиновой изоляцией с оплеткой из волокнистых материалов и без оплетки*	
АПН	(5) Провод с алюминиевой жилой с найритовой резиновой изоляцией без оплетки	ТУКП 36-58
АПР	(6) Провод с алюминиевой жилой в оплетке из хлопчатобумажной пряжи, пропитанной противогнилостным составом	ГОСТ 5352-52
АПРТО	(7) Провод с алюминиевой жилой в оплетке из хлопчатобумажной пряжи, пропитанной противогнилостным составом, для прокладки в основном в стальных трубах	ТУКП 37-58
АПРВ	(8) Провод с алюминиевой жилой в полихлорвиниловой оболочке одножильный	ТУКП 2-59
АР	(9) Провод с медной жилой арматурный в непропитанной оплетке из хлопчатобумажной пряжи одножильный	ГОСТ 1977-54
АРД	(10) Провод с медными жилами арматурный в непропитанной оплетке из хлопчатобумажной пряжи двухжильный	ГОСТ 1977-54
ДПРГ	(11) Провод с медными жилами гибкий в общей оплетке из хлопчатобумажной пряжи, пропитанной противогнилостным составом двухжильный	ГОСТ 1977-54
ПР	(12) Провод с медной жилой в оплетке из хлопчатобумажной пряжи, пропитанной противогнилостным составом, одножильный	ГОСТ 1977-54
ПРГ	(13) Провод с медной жилой гибкий в оплетке из хлопчатобумажной пряжи, пропитанной противогнилостным составом	ГОСТ 1977-54
ПРГЛ	(14) Провод с медной жилой гибкий в оплетке из хлопчатобумажной пряжи, покрытой лаком	ГОСТ 1977-54
ПРД	(15) Провод с медными жилами гибкий в непропитанной оплетке из хлопчатобумажной пряжи двухжильный	ГОСТ 1977-54
ПРЛ	(16) Провод с медной жилой в оплетке из хлопчатобумажной пряжи, покрытой лаком	ГОСТ 1977-54
ПРТО	(17) Провод с медными жилами в оплетке из хлопчатобумажной пряжи, пропитанной противогнилостным составом, для прокладки в основном в стальных трубах	ВТУЭ 128-43
ПРВ	(18) Провод с медной жилой в полихлорвиниловой оболочке одножильный	ТУКП 0-72-66
ПРГВ	(19) Провод гибкий с медной жилой в полихлорвиниловой оболочке одножильный	ТУКП 0-72-66
ПРВД	(20) Провод гибкий с медными жилами в полихлорвиниловой оболочке двухжильный	ТУКП 0-72-66
ШР	(21) Шнур с медными жилами в непропитанной оплетке из хлопчатобумажной пряжи двухжильный	ГОСТ 1977-54
РКГМ	(22) Провод гибкий теплостойкий с медной жилой с изоляцией из кремнийорганической резины в оплетке из стекловолокна, пропитанной кремнийорганическим лаком, одножильный	ВТУ МЭП ОАА 505. 027-53
АТРГ	(23) Провод тросовый с алюминиевыми жилами в оболочке из найритовой резины	ТУКП 69-59
	(24) *2. Установочные провода с резиновой изоляцией в металлических защитных оболочках*	
ПРП	(25) Провод с медной жилой панцирный в защитной оплетке из стальной оцинкованной проволоки	ГОСТ 1843-46
ПРШП	(26) Провод с медной жилой панцирный в шланговой оболочке и оплетке из стальных оцинкованных проволок	ГОСТ 1843-46
ТПРФ	(27) Провод с медной жилой в трубчатой металлической фальцованной оболочке	ГОСТ 1843-46
АТПРФ	(28) То же с алюминиевой жилой	ТУКП 98-60

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Continuation Table 2-3.

	(29) *3. Установочные провода с полихлорвиниловой изоляцией*	
АПВ	(30) Провод с алюминиевой жилой	ГОСТ 6323-62
ПВ	(31) Провод с медной жилой	ГОСТ 6323-62
ПГВ	(32) Провод с гибкой медной жилой	ГОСТ 6323-62
ППВ	(33) Провод плоский с медными жилами с разделительным основанием	ГОСТ 6323-62
АППВ	(34) То же с алюминиевыми жилами	ГОСТ 6323-62
ППВС	(35) Провод плоский с медными жилами без разделительного основания	ГОСТ 6323-62
АППВС	(36) То же с алюминиевыми жилами	ГОСТ 6323-62
УВГ	(37) Провод с гибкой медной жилой	ТУК 281-57
УВОГ	(38) Провод с особо гибкой медной жилой	ТУК 281-57
	(39) *4. Шнуры для бытовых электроприборов*	
ШВРО	(40) Шнур с резиновой изоляцией скрученный с заполнением в общей оплетке из хлопчатобумажной пряжи, лощеной нитки, натурального или искусственного шелка	ГОСТ 7399-55
ШВРШ	(41) Шнур с резиновой изоляцией скрученный с заполнением в шлантовой резиновой оболочке	ГОСТ 7399-55
ШПВ	(42) Шнур с двумя параллельно уложенными жилами в общей изоляции из полихлорвинилового пластиката	ГОСТ 7399-55
ШПО (44) и ШПРО	(43) Шнур с изоляцией из хлопчатобумажной пряжи двухжильный с параллельно уложенными жилами в общей оплетке из хлопчатобумажной пряжи, лощеной нитки, натурального или искусственного шелка	ГОСТ 7399-55
ШВВШ	(45) Шнур с медными жилами с полихлорвиниловой изоляцией скрученный в полихлорвиниловой оболочке	ТУК 271-57
	(46) *5. Провода и кабели с алюминиевыми жилами для преимущественного применения в сельском хозяйстве*	
АВВГ	(47) Кабель с поливинилхлоридной изоляцией в поливинилхлоридной оболочке	ГОСТ 11160-65
АВПГ	(48) То же с полиэтиленовой изоляцией	ГОСТ 11160-65
АППР	(49) Провод с резиновой изоляцией для прокладки по деревянным основаниям	ТУ 017-31-63
АСВ-1	(50) Кабель самонесущий со стальным тросом с изоляцией из светостойкого пластиката. Трос допускает усилие 230 *кГ*	ТУ 017-32-63
АСВ-2	(51) То же. Усилие 650 *кГ*	ТУ 017-32-63

Key: (1). Brand. (2). Designation of wires and cords. (3). or. (4). 1. Black cables and cords with rubber insulation with braid/cover from fibrous materials and without braid/cover. (5). Wire with

aluminum vein/strand with neoprene rubber insulation without braid/cover. (6). Wire with aluminum vein/strand in braid/cover from cotton thread, saturated with preservative composition. (7). Wire with aluminum vein/strand in braid/cover from cotton thread, saturated with imputrescible composition, for separator in essence in steel tubes. (8). Wire with aluminum vein/strand in polychlorovinyl shell single-cable. (9). Wire with copper vein/strand reinforcing in unimpregnated braid/cover from cotton thread single-cable. (10). Wire with copper veins/strands reinforcing in unimpregnated braid/cover from cotton thread twin-cored. (11). Wire with copper veins/strands flexible in general/common/total braid/cover from cotton thread, saturated with imputrescible composition twin-cored. (12). Wire with copper vein/strand in braid/cover from cotton thread, saturated with imputrescible composition, single-cable. (13). Wire with copper vein/strand flexible in braid/cover from cotton thread, saturated with imputrescible composition. (14). Wire with copper vein/strand flexible in braid/cover from cotton thread, covered with varnish. (15). Wire with copper veins/strands flexible in unimpregnated braid/cover from cotton thread twin-cored. (16). Wire with copper vein/strand in braid/cover from cotton thread, covered with varnish. (17). Wire with copper veins/strands in braid/cover of their cotton thread, saturated with imputrescible composition, for separator in essence in steel tubes. (18). Wire with copper vein/strand in polychlorovinyl shell single-cable. (19). Wire flexible with copper

vein/strand in polychlorovinyl shell single-cable. (20). Wire flexible with copper veins/strands in polychlorovinyl shell twin-cored. (21). Cord with copper veins/strands in unimpregnated braid/cover from cotton thread twin-cored. (22). Wire flexible heat-resistant with copper vein/strand with insulation from silicon rubber in braid/cover from fiberglass, saturated with silicon varnish, single-cable. (23). Wire cable with aluminum veins/strands in shell from neoprene rubber. (24). 2. Adjusting rubber-covered wires in metal shielding shells. (25). Wire with copper vein/strand armored in shielding braid/cover from steel zinc-coated wire. (26). Wire with copper vein/strand armored in hose shell and braid/cover from steel zinc-coated wires. (27). Wire with copper vein/strand in tubular metal folded shell. (28). Then with aluminum vein/strand. (29). 3. Black cables with polychlorovinyl insulation. (30). Wire with aluminum vein/strand. (31). Wire with copper vein/strand. (32). Wire with flexible copper vein/strand. (33). Wire flat/plane with copper veins/strands with separating foundation. (34). Then with aluminum veins/strands. (35). Wire flat/plane with copper veins/strands without separating foundation. (36). Then with aluminum veins/strands. (37). Wire with flexible copper vein/strand. (38). Wire with especially flexible copper vein/strand. (39). 4. Cords for domestic electric appliances. (40). Cord with rubber insulation twisted with filling in general/common/total braid/cover from cotton thread, glossy filament, natural or artificial silk. (41). Cord with

rubber insulation twisted with filling in hose rubber shell. (42). Cord with two in parallel by packed veins/strands in overall insulation from polychlorovinyl plastic material. (43). Cord with insulation from cotton thread twin-cored with in parallel packed veins/strands in general/common/total braid/cover from cotton thread, glossy filament, natural or artificial silk. (44). and. (45). Cord with copper veins/strands with polychlorovinyl insulation twisted in polychlorovinyl shell. (46). 5. Wires and cables with aluminum veins/strands for preferred use/application in agriculture. (47). Cable with polyvinyl chloride insulation in polyvinyl chloride shell. (48). The same, with polyethylene insulation. (49). Rubber-covered wire for separator on wooden foundations. (50). Cable, which is self-supporting with steel cable with insulation from lightproof plastic material. Cable allows/assumes effort/force 230 kgf. (51). The same. Effort/force 650 kgf.

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Table 2-4. The ranges of the sections of wires and cords in depending on a number of strands and voltage.

(1) Марка провода и шнура	(2) Число жил	(3) Диапазоны сечений жил, мм², при номинальном напряжении, в				
		220	380	500	2 000	3 000
(4) *1. Провода и шнуры с резиновой изоляцией*						
АПН	1	—	—	2,5—6	—	—
АПН	2,3	—	—	2,5—4	—	—
АПР	1	—	—	2,5—400	—	—
АПРТО	1	—	—	2,5—400	2,5—400	—
АПРТО	2, 3, 4	—	—	2,5—120	2,5—120	—
АПРВ	1	(5)	—	2,5—6	—	—
АР	1	0,5 и 0,75	—	—	—	—
АРД	2	0,5 и 0,75	—	—	—	—
		(5)				
ДПРГ	2	—	0,5—10	—	—	—
ПРД	2	—	0,5—6	—	—	—
ПР, ПРГ	1	—	—	0,75—400	—	1,5—185
ПРГЛ	1	—	—	0,75—70	—	—
ПРЛ	1	—	—	0,75—6	—	—
ПРТО	1	—	—	1—500	1—500	—
ПРТО	2, 3, 4	—	—	1—120	1—120	—
ПРВ	1	—	—	0,75—6	—	—
ПРГВ	1	—	—	0,75—6	—	—
ПРВД	2	—	0,5—6	—	—	—
ШР	2	0,5—1,5	—	—	—	—
РКГМ	1	—	0,75—95	—	—	—
(6) *2. Провода с резиновой изоляцией и металлической защитной оболочке*						
ПРП, ПРШП	1, 2, 3, 4	—	—	1—95	—	—
ТПРФ	1, 2, 3, 4	—	—	1—10	—	—
АТПРФ	2, 3	—	—	2,5—4	—	—
(7) *3. Установочные провода с полихлорвиниловой изоляцией*						
ПВ, ПВГ	1	—	—	0,75—95	—	—
АПВ	1	—	—	2,5—120	—	—
ППВ, ППВС	2, 3	—	—	0,75—4	—	—
АППВ, АППВС	2, 3	—	—	2,5—6	—	—
УВГ	1	—	1,5—25	—	—	—
УВОГ	1	—	1,5—6	—	—	—

Notes: 1. A number of strands and the sections of coupling cables for the domestic electric appliances were shown in Table 2-6.

2. Four-strand wires of models PRTO and APRTO, and also twin-cored and three-strand wires of models PFP, PRShP and TPRF are manufactured with zero or that grounding with veins/strands whose sections are shown in Table 2-5.

Key: (1). Brand of wire and cord. (2). Number of strands. (3). Ranges of sections of strands, mm^2, with nominal voltage, V. (4). 1. Wires and cords with rubber insulation. (5). and. (6). 2. Rubber-covered wires in metal shielding shell. (7). 3. Black cables with polychlorovinyl insulation.

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Table 2-5. Sections of the zerc (grounding) vein/strand of the wires cf models PRTO, APRTC, EEE, EESbE and TPEF.

(1) Сечение основных (фазных) жил, мм². .	1; 1,5	2,5	4	6	10; 16	25, 35	50	70	95
(2) Сечение нулевой (заземляющей) жилы, мм²	1	1,5	2,5	4	6	10	16	25	35

Key: (1). The section cf bases (phase) of strands, mm². (2). Section of zero (grounding) vein/strand, mm².

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Table 2-6. Recommended brands of wires and cords.

(1) Рекомендуемые марки проводов	(2) Основная область применения	(3) Способ прокладки
ПР-500 АПР-500, ПРВ-500, АПРВ-500	(4) Осветительные и силовые сети внутри сухих и сырых помещений и вне зданий, в пожароопасных помещениях, во вторичных цепях при напряжениях до 500 *в* переменного и 1 000 *в* постоянного тока	(5) В изоляционных трубках, на роликах, изоляторах и клицах, по металлическим и бетонным поверхностям с прокладкой под провода изолирующих материалов
ПР-3000	(6) Осветительные и силовые сети внутри помещений и вне зданий (с импульсными перенапряжениями) при напряжении до 3 000 *в* переменного тока	(7) В стальных трубах, металлических рукавах, на изоляторах
ПРЛ, ПРГЛ	(8) Вторичные цепи, релейные щиты и пульты, распределительные щиты и шкафы при напряжении до 500 *в* переменного и 1 000 *в* постоянного тока; ПРГЛ употребляется в случаях, когда требуется гибкость провода	(9) Открыто по панелям и скрыто в коробах
ПРГ-500, ПРГВ-500	(10) Соединение подвижных частей электрических машин, аппаратов и приборов внутри и вне зданий, по станкам до 500 *в* переменного и 1 000 *в* постоянного тока	(11) В металлических рукавах
ПРГ-3000	(12) То же постоянного или переменного тока до 3 000 *в*	(13) То же
ПВ АПВ	(14) Осветительные и силовые сети внутри помещений (сухих, сырых, особо сырых, с парами минеральных кислот и щелочей) при температуре окружающей среды не выше +40° C, осветительные щиты, пусковые ящики, закрытые шкафы до 500 *в* переменного и 1 000 *в* постоянного тока и для вторичных цепей	(15) В трубах, на роликах, изоляторах и клицах, по металлическим и бетонным поверхностям с прокладкой под провода изолирующих материалов
ПГВ	(16) Осветительные и силовые сети, вторичные цепи станков и механизмов при наличии масел и эмульсии до 500 *в* переменного тока и 1 000 *в* постоянного тока	(17) В трубах и металлических рукавах
ПРД ПРВД	(18) Осветительные сети в сухих и отапливаемых помещениях	(19) На роликах
ПРТО-500 АПРТО-500	(20) Осветительные и силовые сети во взрывоопасных помещениях; провода марки ПРТО — также по вибрирующим поверхностям машин, агрегатов и кранов в случаях, когда вскрытие трубопроводов представляет большие трудности (например, прокладка труб под художественной облицовкой), а также во вторичных цепях до 500 *в* переменного и 1 000 *в* постоянного тока	(21) В стальных трубах и металлических рукавах
ПРТО-2000 АПРТО-2000	(22) Осветительные и силовые сети, вторичные цепи (с импульсными перенапряжениями) до 2 000 *в* переменного тока	(23) То же

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Continuation Table 2-6.

ПРП	(23) Осветительные и силовые сети, вторичные цепи станков и механизмов при наличии легких механических воздействий на провод и отсутствии воздействий на провод масел и эмульсии до 500 *в* переменного и 1 000 *в* постоянного тока	(24) Открыто с закреплением скобками
ПРШП	(25) Осветительные и силовые сети, вторичные цепи мостовых кранов, экскаваторов, машин и механизмов при наличии механических воздействий на провод и отсутствии воздействий масел, эмульсий и т. п. до 500 *в* переменного и 1 000 *в* постоянного тока	(13) То же
ТПРФ, АТПРФ	(26) Осветительные и силовые сети в сухих помещениях при наличии легких механических воздействий на провод (например, проводки в лестничных клетках), а также в тех случаях, когда открытую проводку по архитектурным соображениям выполняют незаметной (клубы, кино, театры, музеи и т. п.) до 500 *в* переменного и 1 000 *в* постоянного тока	(24) Открыто с закреплением скобками
АР, АРД	(27) Зарядка осветительных арматур в сухих помещениях при напряжении до 220 *в* между жилами в том случае, если от проводов не требуется гибкости	(28) Внутри и поверх осветительных арматур, кроме светильников с люминесцентными лампами
ДПРГ	(29) Зарядка осветительных арматур вне зданий и в сырых помещениях при напряжении до 220 *в* в том случае, если провода должны обладать гибкостью	(30) Внутри осветительной арматуры, кроме светильников с люминесцентными лампами.
ШР	(31) Присоединение подвижных электроприемников в сухих помещениях к сетям с номинальным напряжением между жилами до 220 *в*	(32) Открыто
РКГС	(33) Выводы электродвигателей с повышенной температурой, прокладки в установках, требующих теплостойкости до 180° С в сетях с номинальным напряжением до 380 *в*	(34) Открыто в трубах, в металлических рукавах
АПН	(35) Осветительные сети и сети мелких силовых нагрузок (до 1 *квт*) в сухих и сырых помещениях по стенам и потолкам в сетях с номинальным напряжемем до 380 *в*	(32) Открыто
ППВ, АППВ	(36) Осветительные сети внутри помещения по стенам и потолкам в сухих и сырых помещениях	(37) Открыто и скрыто (под штукатуркой или в строительных конструкциях)
ППВС, АППВС	(13) То же	(38) Скрыто под штукатуркой или в строительных конструкциях
УВГ, УВОГ	(39) В полевых условиях	(40) Фиксированная прокладка
ШВРО:		
2×0,5 *мм*²	(41) Для дорожных утюгов, медицинских грелок и электропаяльников	—
2×0,75 *мм*²	(42) Для утюгов	—
2×1 *мм*²	(43) Для утюгов свыше 600 *вт*	—

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Continuation Table 2-6.

3×0,75 мм²	(44) Для переносных электроприборов в условиях, требующих заземления электроприбора	—
ШПРО: 2×0,5 мм²	(45) Для настольных ламп, вентиляторов, сферических отражателей, телевизоров, медицинских рефлекторов	—
2×0,75 мм²	(46) Для настольных ламп, плиток, чайников, кофейников, кастрюль, удлинителей, телевизоров и трансформаторов к бытовым приборам	—
ШВРШ: 2×0,75 мм²	(47) Для холодильников, пылесосов, электрополотеров, стиральных машин и удлинителей	—
2×1 мм²	(48) Для плиток свыше 600 вт	—
3×0,75 мм²	(49) Для холодильников, пылесосов, электрополотеров, стиральных машин и удлинителей в условиях, требующих заземления электроприбора	—
3×1 мм²	(50) Для плиток свыше 600 вт в условиях, требующих заземления	—
ШПВ: 2×0,35 мм²	(51) Для абонентских громкоговорителей и электробритв	—
2×0,5 мм²	(52) Для радиоприемников, телевизоров, радиограммофонов, электропроигрывателей и магнитофонов	—
2×0,75 мм²	(13) То же	—
ШПО 2×0,35 мм²	(53) Для абонентских громкоговорителей	—
ШВВШ 3×0,35 мм²	(54) К электрическим машинкам для стрижки волос	—

Key: (1). Recommended brands of wires. (2). Fundamental field of application. (3). Method of separator. (4). Lighting and power networks/grids of inside dry and damp/crude locations and out of buildings, in flammable locations, in secondary circuits with voltages to 500 V of variable/alternating and 1000 V of direct current. (5). In insulating tubes, on rollers, insulators and cleats, over metallic and concrete surfaces with separator for wires of insulating materials. (6). Lighting and power networks/grids indoors

and out of buildings (with pulse overvoltages) with voltage to 3000 V of alternating current. (7). In steel tubes, metallic hoses/pipes, on insulators. (8). Secondary circuits, relay panels and panels, distributing frames and cabinets with voltage to 500 V of variable/alternating and 1000 V of direct current; PRGL are used in cases when is required flexibility of wire. (9). It is opened on panels and it is hidden in ducts. (10). Connection of moving elements of electric machines, apparatuses and instruments inside and out of buildings, on machine tools to 500 V of variable/alternating and 1000 V of direct current. (11). In metallic hoses/pipes. (12). The same, of direct or alternating current to 3000 V. (13). The same. (14). Lighting and power networks/grids indoors (dry, damp/crude, very dry, with vapors of mineral acids and alkalies) at ambient temperature not are higher than +40°C, lighting panels, starting/launching cabinets, closed cabinets to 500 V of variable/alternating and 1000 V of direct current, also, for secondary circuits. (15). In tubes, on rollers, insulators and cleats, over metallic and concrete surfaces with separator for wires of insulating materials. (16). Lighting and power networks/grids, secondary circuits of machine tools and mechanisms in presence of oils and emulsion to 500 V of alternating current and 1000 V of direct current. (17). In tubes and metallic hoses/pipes. (18). Lighting systems in dry and heated locations. (19). On rollers. (20). Lighting and power networks/grids in dangerously explosive locations; wire of model PRTO - also over jarring surfaces of

machines, aggregates/units and taps/cranes in cases when opening of conduits/manifolds presents great difficulties (for example, tubing under artistic casing), and also in secondary circuits to 500 V of variable/alternating and 1000 V of direct current. (21). In steel tubes and metallic hoses/pipes. (22). Lighting and power networks/grids, secondary circuits (with pulse overvoltages) to 2000 V of alternating current. (23). Lighting and power networks/grids, secondary circuits of machine tools and mechanisms in presence of light mechanical effects on wire and absence of effects on wire of oils and emulsion to 500 V of variable/alternating and 1000 V of direct current. (24). It is opened with attachment by brackets. (25). Lighting and power networks/grids, secondary circuits of bridge cranes, excavators, machines and mechanisms in presence of mechanical effects on wire and absence of effects of oils, emulsions and the like to 500 V of variable/alternating and 1000 V of direct current. (26). Lighting and power networks/grids in dry locations in presence of light mechanical effects on wire (for example, wiring in staircases), and also when open wiring for architectural reasons is fulfilled by imperceptible (clouds/clubs/puffs, cinema, theaters, museums, etc.) to 500 V of variable/alternating and 1000 V of direct current. (27). Charging of fittings in dry locations with voltage to 220 V between veins/strands in such a case, when of wires it is not required for flexibility. (28). Within and above fittings, besides illuminating lamps with fluorescent lamps. (29). Charging of fittings

out of buildings and in damp/crude locations with voltage to 220 V in such a case, when wires must possess flexibility. (30). Within fittings, besides illuminating lamps with fluorescent lamps. (31). Connection of movable electrical receivers in dry locations to networks/grids with nominal voltage between veins/strands to 220 V. (32). It is opened. (33). Conclusion/output of electric motors with elevated temperature, separator in installations, requiring heat resistance to 180°C in networks/grids with nominal voltage to 380 V. (34). It is opened in tubes, in metallic hoses/pipes. (35). Lighting systems and networks/grids of fine/small power loads (to 1 kW) in dry and damp/crude locations on walls and ceilings in networks/grids with nominal voltage to 380 V. (36). Lighting systems indoors on walls and ceilings in dry and damp/crude locations. (37). It is opened and it is hidden (under plastering or in structures). (38). It is hidden under plastering or in structures. (39). Under field conditions. (40). Fixed/recorded separator. (41). For road irons, medical heaters and electric soldering irons. (42). For irons. (43). For irons it is more than 600 W. (44). For movable electric appliances under conditions, which require grounding of electric appliance. (45). For table lamps, fans, spherical reflectors, television sets, medical reflectors. (46). For table lamps, blocks, teapots, coffee pots, cockers, extenders, television sets and transformers to household devices. (47). For coolers, vacuum cleaners, electric polishers, washing machines and extenders. (48). For blocks it is more than 600

W. (49). For coolers, vacuum cleaners, electric polishers, washing machines and extenders under conditions, which require grounding of electric appliance. (50). For clocks it is more than 600 W under conditions, which require grounding. (51). For user loudspeakers and electric razors. (52). For radio receivers, television sets, radio-phonographs, electric record players and magnetic recorders. (53). For user loudspeakers. (54). To electrical typewriters/machines for hair-cutting of hair.

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Table 2-7. Selection of the method of wiring in the lighting systems in depending on the conditions of medium.

(2) Проводка	(3) Провода*	(4) Способ прокладки	(1) Характе... (5) Сухие нормальные: (8) Административные и бытовые	(9) Производственные	(10) Влажные	(11) Сырые	(12) Особо сырые
(18) Открытые по несгораемым и трудносгораемым конструкциям и поверхностям на изолирующих опорах	ПРД, ПРВД	(19) На роликах	×	—	—	—	—
	АПР, АПРВ, АПВ	То же (20)	×	×	×	×*	×*
	АПР, АПРВ, АПВ	На изоляторах (21)	×	+	+	+	+
	Голые (22)	То же (20)	—	×	×	×	×
(23) Открытые струнные и тросовые	АТРГ, АСВ	Перекидные (24)	—	+	+	+	×
	АВВГ, АПВГ, АНРГ, АВРГ, АСРГ	По струне (25)	—	×	+	+	×*
	АПР, АПРВ, АПВ	На тросе (26)	—	+	+	—	—
	ВВБ, АВББ	То же (20)	—	—	—	—	—
(27) Открытые непосредственно по несгораемым и трудносгораемым конструкциям и поверхностям	АПВ, АПРТО, АПРВ, АПР	В винипластовых трубах (28)	+	+	+	+	+
	АПР, АПРВ, АПВ	В бумажно-металлических трубах (29)	+	+	+	—	—
	АПВ, АПРТО	(30) В стальных водогазопроводных обыкновенных трубах	—	—	—	—	—
То же (20)	АПВ, АПРТО АПРВ, АПР	В стальных водогазопроводных тонкостенных трубах (31)	—	+	+	+	+
	АПВ, АПРТО, АПРВ, АПР	(32) В стальных электросварных трубах	—	+	+	—	—

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Continuation Table 2-7.

ристики помещений[1]															
(13) Пыльные	(14) Жаркие	(15) С химически активной средой	(16) Пожароопасные П-I	П-II	П-IIa	П-III	(17) Взрывоопасные В-I	В-Ia	В-Iб	В-Iг	В-II	В-IIa	(16) Наружные проводки	(17) Чердаки
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	×	—	—	—	—	—	—	—	—	—	—	—	×[4]	×[5]
+	+	+	+[6]	+[6]	+[6]	+[6]	—	—	—	—	—	—	+	×[5]
—	×	×	—	—	—	—	—	—	—	—	—	—	—	—
×	×	—	×[6]	×[6]	×	—	—	—	—	—	—	—	+[7]	—
+	+	×[6]	+[6]	+[6]	+[6]	×[6; 8]	—	×[9;]	+[6]	—	—	×[6]	×[6]	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	+	—	—	—	—	—	+[13]	+	+	—	+	—	—
+	—	+	—	—	—	—	—	—	—	—	—	—	+	—
×	×	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	+[12]	+[13]	+	+	+	+	—	—
+	+	+	+	+	+	+	—	—	—	—	—	—	+	+
+	+	—	+	+	+	—	—	—	—	—	—	—	—	×

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Continuation Table 2-7.

(33) Открытые непосредственно по несгораемым и трудносгораемым конструкциям и поверхностям	АПВ, АПР, АПРВ	(34) В коробах и лотках	—	+	+	—	—
	АВВГ, АПВГ, АНРГ, АВРГ, АСРГ	На скобах (35)	×	×	+	+	×
	АТПРФ	То же (20)	+	+	—	—	—
	АППВ, АПН, АППВС	Приклеиванием или на гвоздях (36)	+	×	×	×	—
	ВББ, АВББ	(35) На скобах	—	—	—	—	—
(37) Открытые по сгораемым конструкциям и поверхностям	ПРД, ПРВД	(19) На роликах	+	+	—	—	—
	АПР, АПРВ, АПВ	То же (20)	×	+	+	+[2]	+[2]
	АПР, АПРВ, АПВ	На изоляторах (21)	—	+	+	+	+
	АТПРФ	На скобах (35)	+	+	—	—	—
То же (20)	АППВ, АПН	(19) На роликах[1]	+	+	+	×[3]	×[3]
	АППР	На скобах[1] (35)	+	+	+	—	—
(38) Скрытые в несгораемых стенах, перекрытиях и конструкциях	АПР, АПРВ, АПВ	(29) В бумажно-металлических трубах	+	+	+	—	—
	АПВ, АПРТО, АПРВ, АПР	В винипластовых или полиэтиленовых трубах (39)	+	+	+	+	+
	АПР, АПВ, АПРВ	(40) В резинобитумных трубах	+	+	+	—	—

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Continuation Table 2-7.

−	+	−	−	−	−	−	−	−	−	−	−	−	−	−
+	×	×	+	+	+	+	−	+[9,12]	+[9]	−	−	+[9]	+	+
+	+	−	−	+[10]	+[10]	−	−	−	×	−	−	−	−	−
+	−	−	−	−	−	−	−	−	−	−	−	−	−	−
−	−	+	−	−	−	−	−	+[12]	+	+	−	+	−	−
−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
−	+	−	−	−	−	−	−	−	−	−	−	−	−	−
+	+	+	−	−	−	−	−	−	−	−	−	−	−	−
−	+	−	−	−	−	−	−	−	−	−	−	−	−	−
−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
×	×	−	−	−	−	−	−	−	−	−	−	−	−	−
+	−	+	−	−	−	−	−	−	−	−	−	−	−	−
×	−	−	−	×	×	−	−	−	−	−	−	−	−	−

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Continuation Table 2-7.

38 Скрытые в несгораемых стенах, перекрытиях и конструкциях	АПВ, АПРТО	30 В стальных водогазопроводных обыкновенных трубах	—	—	—	—	—
То же 20	АПВ, АПРТО, АПРВ	41 То же в тонкостенных водогазопроводных трубах	—	+	+	+	+
		42 То же в электросварных трубах	—	+	+	—	—
	АППВС, АПН, АПВ	43 В замкнутых каналах строительных конструкций и под штукатуркой	+	×	+	+	—
	АППВС	44 Путем замоноличивания в строительной конструкции	+	×	+	+	—

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−	−	−	−	−	−	−	+[12]	+[12]	+	+	+	+	+	−
+	+	+	+	+	+	+	−	−	−	−	−	−	+	+
+	+	−	+	+	+	−	−	−	−	−	−	−	−	+
−	−	−	−	−	−	−	−	−	−	−	−	−	−	×
−	−	−	−	−	−	−	−	−	−	−	−	−	−	×

Key: (1). Characteristics or locations[1].

FOOTNOTE 1. + - it is recommended; x - is allowed/assumed; - - is forbidden or use/application inexpediently. ENDFOOTNOTE.

(2). Wiring. (3). Wires [2].

FOOTNOTE 2. Cables and wires with the polychlorcvinyl or polyvinyl chloride insulation and the shell (APV; APRV; AVRG; AVVG, etc.) apply instead of wires and india-rubber cables with the medium, agressive with respect to rubber (with the possibility of the effect of cils, emulsion), in the damp/crude and especially damp/crude locations, and also with the chemically active medium. In the external wirings are applied the rubber-covered wires (APR); the cables of brands AVRG, AVVG it is necessary to protect from the straight/direct solar rays/beams. ENDFOOTNOTE.

(4). Method of separator. (5). Dry normal. (6). Flammable. (7). Dangerously explosive. (8). Administrative and everyday. (9). Production. (10). Humid. (11). Damp/crude. (12). Especially damp/crude. (13). Dusty. (14). Hot. (15). With chemically active medium. (16). External wirings. (17). Garrets. (18). Opened by incombustible and nonflammable constructions/designs and over surfaces on insulating supports. (19). On rollers. (20). Then. (21). On insulators. (22). Bare. (23). Open string and cable. (24). Reversing. (25). On drop. (26). On cable. (27). Opened it is direct by incombustible and nonflammable constructions/designs and over surfaces. (28). In PVC plastic tubes. (29). In paper- metallic tubes. (30). In steel water-gas conducting usual tubes. (31). In steel

water-gas conducting thin-walled tubes. (32). In steel electric welding tubes. (33). Opened it is direct by incombustible and nonflammable constructions/designs and over surfaces. (34). In ducts and chutes/trays. (35). On clamps. (36). By glueing or on nails. (37). Opened by combustible constructions/designs and over surfaces. (38). Hidden in incombustible walls, overlaps and constructions/designs. (39). In polyvinyl chloride or polyethylene tubes. (40). In rubber-bitumen tubes. (41). Then in thin-walled water-gas conducting tubes. (42). Than in electric welding tubes. (43). In locked channels of structures and under plastering. (44). By method of monolithization in structure.

FOOTNOTE [3]. Is allowed/assumed separator on the rollers for the damp/crude places.

[4]. It is allowed/assumed in places, shielded from direct incidence/impingement of residues/settlings, on rollers - for damp/crude places.

[5]. Is permitted separator on rollers only for non-industrial of buildings at height/altitude of separator not less than 2.5 m, but on insulators - for any buildings.

6. Wires must be distant from places of accumulation of fuels and unavailable for mechanical effects.

7. Is recommended wire of model ASV for entrances in rural locality.

8. Is allowed/assumed during use/application of drop or dew from materials, immune to corrosion.

9. Separator can be fulfilled in the absence of possibility of mechanical and chemical effects.

10. It is allowed/assumed in the absence of the dust, which forms with the moisture of the connections, which destroy those operating on metallic shell.

11. Is permitted separator for the locations in the rural localities.

12. For the locations of the classes V-I and VIa it is applied wire and cables with the copper veins/strands.

Notes: 1. The technical floors airtight buildings are ones without skylights are considered as the production locations (but not garrets).

2. For concealed wiring in dry and humid locations is allowed/assumed separator of thin-walled electric welding tubes under condition of connection by their clutches on knurl thread.

[13]. Table is borrowed from [23]. ENDFOOTNOTE.

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The current-carrying veins/strands of wires single-wire and stranded (flexible) are manufactured from the round copper or aluminum wire.

The wire insulation and cords is manufactured from rubber or polychlorovinyl plastic material. As the shielding deposit of wires and cords with the rubber insulation serves the braid/cover from fibrous materials, saturated or not saturated with imputrescible composition. Wires and cords with the polychlorovinyl insulation, as a rule, are manufactured without the shielding deposits.

The enumeration of the brands of wires and cords with the rubber and polychlorovinyl insulation is given in Tables 2-3, and the ranges

of sections TABLE 2-4.

When selecting cf the brands cf wires and cords should be been guided by designation/purpose their, operating voltage and environmental conditions.

Table 2-6 gives recommendations by choice cf wires and cords with the rubber and polychlorovinyl insulation.

Table 2-7 gives recommendations by choice of the method of separator for the lighting systems.

2-3. Power cables.

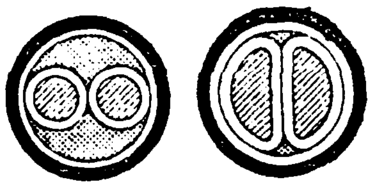
Power cables are intended for transmission and distributing electrical energy under the most diverse conditions of separator (in the earth/ground, under water, in the open air and indoors).

The current-conducting veins/strands of power cables are manufactured from aluminum or electrolytic copper. The sections of the aluminum and copper current-conducting veins/strands are received as standard ones. In form the current-conducting veins/strands are divided into the circular ones, the segmental ones and the sector ones.

Power cables are manufactured with the paper, rubber or molded insulation of strands. The thickness of insulating layer depends on the section of veins/strands and nominal voltage of cable.

For the protection of isolation from the moistening and the chemical effects of the environment power cables are covered/coated with shell of aluminum, lead, polyvinyl chloride or incombustible rubber.

For the preservation from the mechanical damages serves the armor, fulfilled from the steel tapes or the circular steel wires.



a) b)

Fig. 2-4. Two-core cable. a) with the round veins/strands; b) with the segmental veins/strands.

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The cables, run in the earth/ground, above the armor are covered/coated with external shielding shell of the cable braid/cover, saturated with bituminous composition, which shields cable armature from the corrosion.

The constructions/designs of cables with the paper insulation are represented in Fig. 2-4-2-9, and with the rubber insulation - in Fig. 2-10 and 2-11.

The enumeration of brands and the range of the sections of cables to 10 kV are given in Table 2-8.

During the designation of cables are accepted the following

conditional letterings (are explained in the crder their sequences):

Letter "A", set in the beginning of designation, a cable with aluminum veins/strands (cable with the copper veins/strands does not have special designaticn and differs from cable with the aluminum veins/strands in terms of the absence of letter "A" in the beginning of designation).

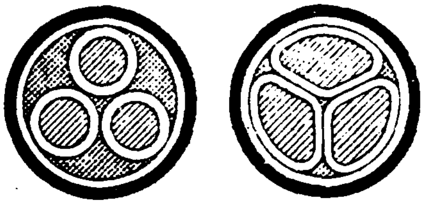
Letter "Ts" - the not discharging saturating paper insulation composition on the base of ceresin-80 (oil-resin saturating composition is characterized by the absence of letter "Ts" in the designation of cable).

Insulaticn of strands of cable:

P - polyethylene;

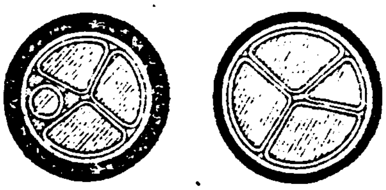
V - PVC;

R - rubber.



a) b)

Fig. 2-5. Triple-core cable. a) with the round veins/strands; b) with the sector strands.



a) b) Fig. 2-6.

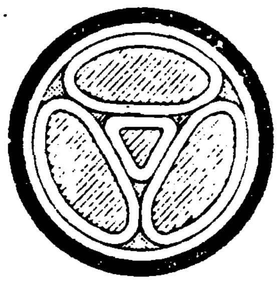


Fig. 2-7.

Fig. 2-6. Four-wire cable. a) with the sector fundamental veins/strands in the circular zero; b) with the sector veins/strands.

Fig. 2-7. Four-strand cable with zero vein/strand in center.

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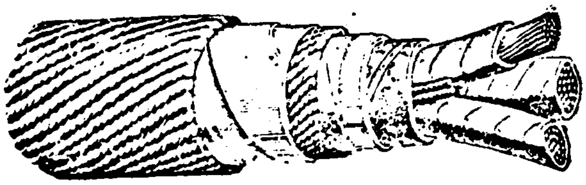

Fig. 2-8. Power cable with strip/tape armor and external deposits from saturated cable yarn of brand SB.

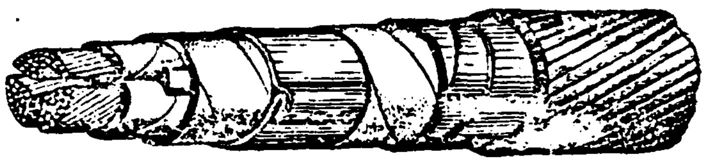

Fig. 2-9. Power cable in aluminum shell with cold-welded joint.

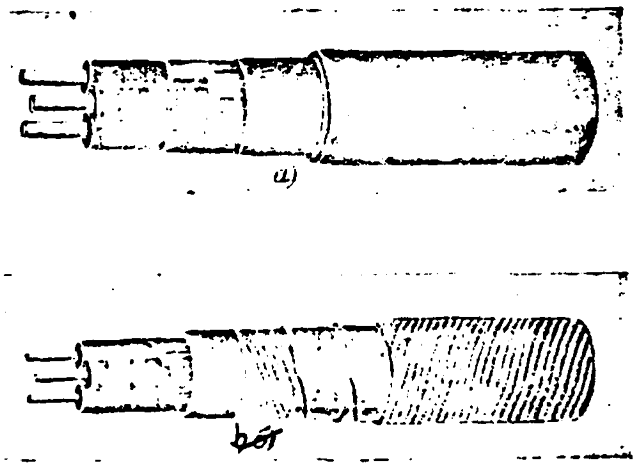

Fig. 2-10. Cables power with rubber insulation in lead covering. a)

not armored of brand SBG; b) armored with the external deposit of brand SRB.

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The separately hose-covered or covered with metal shells cable cores are designated by letter "C".

The material of cable sheathing:

A - aluminum;

S - lead;

V - polychlorovinyl;

N - incombustible rubber.

Index "gv" designates the fluted shell with the polychlorovinyl hose, letter "Sh" - aluminum shell with the cold-welded joint.

The shielding deposits of cable have designations according to GOST 7006-62:

B - armor of two steel tapes with the shielding external deposit;

BG - armor of two steel tapes without the external deposit;

K - armor from the circular steel zinc-coated wires with the shielding external deposit;

KG - armor from the steel circular zinc-coated wires without the external deposit.

Letter "T" at the end of the brand designates, that the cable is intended for the separator in the tubes or the blocks.

Designations 1K and 2K indicate the presence in the cable of one or two pilot wires.

For example, brand ATsABG designates: power cable with aluminum strands (A) with the paper insulation, saturated with non-flowing mass on a ceresin base (Ts), in aluminum shell (A), armored by two steel tapes (B), without the external deposit (G). Cable of brand SK - power cable with the copper veins/strands with the paper insulation, saturated with oil-rosin composition, in the lead covering (S), armored by the steel round zinc-coated wires (K) with the shielding external deposit.

Cables with the paper saturated insulation in the aluminum shell are manufactured according to GOST 6516-55, in the lead covering - according to GOST 340-59, india-rubber cables - according to GOST 433-58. Cables power with the plastic insulation in the plastic shell are manufactured in accordance with the technical specifications MRTU-2-43-61, MRTU-2-43-13-61 and TUKP-127-67.

The basic areas of employment of the basic power cable brands, depending on environmental conditions and methods of laying are presented in Table 2-12.

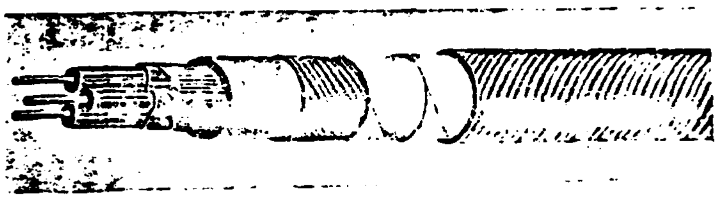

Fig. 2-11. Cable with the rubber insulation in the polychlorcvinyl shell armored with the external deposit of brand VRB.

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Table 2-8. The assortment of power cables on the brands, to the section of those conducting current cores and to nominal voltage.

(a) Марка кабеля	(b) Число жил	(c) Номинальное напряжение, кв				
		0,66	1	3	6	10
		(d) Диапазон сечений, мм²				
1. Кабели с бумажной изоляцией, пропитанной маслоканифольным составом						
ААГ	1	—	35—800	6—625	10—185	16—185
	2	—	35—150	—	—	—
	3	—	35—240	6—240	10—240	16—240
	4	—	35—185	—	—	—
ААБ, ААБГ	1	—	35—800	6—625	10—185	16—185
	2	—	35—150	—	—	—
	3	—	35—240	6—240	10—240	16—240
	4	—	25—185	—	—	—
ААГгв	3	—	35—240	6—240	10—240	16—240
ААБ-1К, ААБ-2К	1	—	185—800	—	—	—
АСГТ	3	—	35—240	4—240	10—240	16—240
СГТ	1	—	35—800	6—625	10—185	16—185
	2	—	35—150	—	—	—
	3	—	35—240	4—240	10—240	16—240
	4	—	35—185	—	—	—
СБ, СБГ	1	—	35—800	6—625	10—185	16—185
	2	—	35—150	—	—	—
	3	—	35—240	4—240	10—240	16—240
	4	—	25—185	—	—	—
СК	3	—	25—240	25—240	16—240	16—240
	4	—	25—120	—	—	—
2. Кабели с бумажной изоляцией, пропитанной нестекающей массой на основе церезина						
ЦСБ, ЦСБГ, ЦСК, ЦСКГ	1	—	35—240	—	10—185	16—185
	2	—	35—150	—	—	—
	3	—	35—240	—	10—185	25—185
	4	—	35—185	—	—	—
АЦАБ, АЦАБГ, АЦАГ	1	—	35—240	6—240	10—185	16—185
	2	—	35—150	—	—	—
	3	—	35—240	6—240	10—240	16—240
	4	—	35—185	—	—	—

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Continuation Table 2-8.

a Марка кабеля	b Число жил	c Номинальное напряжение, кв				
		0,66	1	3	6	10
		d Диапазон сечений, мм²				
3. Кабели с бумажной изоляцией, пропитанной маслоканифольным составом, в алюминиевой оболочке с холодносварным швом						
ААША, ААШБ, ААШБГ	3; 4	—	6—35	—	—	—
4. Кабели с резиновой изоляцией						
АВРГ, АНРГ, АВРБ, АНРБ, АВРБГ, АНРБГ, ВРБ, ВРБГ, НРБ, НРБГ	1 2; 3 2; 3	4—240 4—185 4—185	— — —	— — —	— — —	— — —
ВРГ, НРГ	1 2; 3	1—240 1—185	— —	— —	— —	— —
СРГ	1 2; 3	1—240 1—185	— —	1,5—500 1,5—70	2,5—500 —	— —
СРБ, СРБГ	2; 3	4—185	—	4—70	—	—
5. Кабели с пластмассовой изоляцией						
АВВГ, АПВГ	1 2 3	2,5—35 2,5—35 2,5—35	— — —	— — —	— — 10—150	— — —
ААВБ, АПВБ	2 3	2,5—35 2,5—35	— —	— —	— 10—150	— —
АПОВБ, АПОВБГ, ПОВБ, ПОВБГ	3	—	—	—	—	16—150
ВВГ-Т, ВВБ-Т, ВВБГ-Т	1; 2; 3	—	1,5—240	40—240	—	—
ВВГ-Т, ВВБ-Т, ВВБГ-Т	4	—	1,5—240	—	—	—

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Continuation Table 2-8.

(a) Марка кабеля	(b) Число жил	(c) Номинальное напряжение, кв				
		0,66	1	3	6	10
		(d) Диапазон сечений, мм²				
АВВГ-Т АВВБ-Т, АВВБГ-Т	1; 2; 3	—	2,5—240	4,0—240	—	—
АВВГ-Т, АВВБ-Т, АВВБГ-Т	4	—	2,5—240	—	—	—
ВВГ-Т	5	—	1,5—25	—	—	—
АВВГ-Т	5	—	2,5—35	—	—	—
АВВГ, АПВГ	2 3	2,5—6 4—16	— —	— —	— —	— —
(6) (облегченные)	4 5 6 7	4—50 6—50 16—50 16—50	— — — —	— — — —	— — — —	— — — —
АПАПВ, АВАПВ (6) (облегченные)	3	—	—	—	—	10—50

Note. Triple-cores cable with the plastic and rubber insulation 0.66 kV can be prepared with the supplementary grounding or zero vein/strand.

Key: (a). Cable make-up. (b). Number of cores. (c). Nominal voltage, kV. (d). Range of sections, mm². (1). Cables with paper insulation, saturated with oil-rosin composition. (2). Cables with paper insulation, saturated with not discharging mass on base of ceresin-80. (3). Cables with paper insulation, saturated with oil-rosin composition, in aluminum shell with cold-welded joint. (4). India-rubber cables. (5). Cables with molded insulation. (6). facilitated.

Table 2-9. The section of zero ones or grounding cores of power four-wire cables.

(a) Сечение основных жил, мм²	(b) Сечение нулевой или заземляющей жилы, мм²	
	(c) Кабели с бумажной изоляцией и облегченные кабели с пластмассовой изоляцией	(d) Кабели с резиновой и пластмассовой изоляцией
1	—	1
1,5	—	1
2,5	—	1,5
4	2,5	2,5
6	4	4
10	6	6
16	10	10
25	16	10
35	16	10
50	25	16
70	25	25
95	35	35
120	35	35
150	50	50
185	50	50

Key: (a). The section of bases of cores mm¹. (b). Section of zero or grounding vein/strand, mm². (c). Cables with paper insulation and sheathed cables with molded insulation. (d). Cables with rubber and molded insulation.

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Table 2-10. The section of zero ones and grounding cores of power cables 1-3 kV with the molded insulation, in plastic shell (TUKP-127-67).

(2) основной жилы	(1) Номинальное сечение, мм²			
	(3) нулевой (четвертой) жилы		(4) заземляющей (пятой) жилы	
	(5) медь	(6) алюминий	(5) медь	(6) алюминий
1,5	1,0 и 1,5	—	1,0	—
2,5	1,5 и 2,5	2,5	1,5	2,5
4	2,5 и 4,0	2,5 и 4	2,5	2,5
6	4 и 6	4 и 6	4	4
10	6 и 10	6 и 10	6	6
16	10 и 16	10 и 16	10	10
25	16	16 и 25	16	16
35	16	16 и 35	—	16
50	25	25 и 50	—	—
70	35	35 и 70	—	—
95	50	50 и 95	—	—
120	70	70 и 120	—	—
150	70	70	—	—
185	95	95	—	—
240	120	120	—	—

Notes. 1. Four-wire cables of brands AVVG-T and VVG-T to voltage 1 kV for lighting systems with fluorescent lamps are manufactured with veins/strands of one section.

2. Five-vein/five-strand cables have four fundamental core of identical section and grounding veins/strands smaller sections.

Power cables with the paper insulation, saturated with oil-rosin composition, without the special devices/equipment (stop clutch) are applied for the separator in the sections of route with the difference in two any points or end preparings, which does not exceed the values, indicated in Table 2-11.

Key: (1). Nominal section, mm^2. (2). fundamental vein/strand. (3). zero (fourth) vein/strand. (4). the grounding (fifth) vein/strand. (5). copper. (6). aluminum.

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For the vertical run are released power triple-cores cable with the insulation from the paper, saturated with the not discharging mass, on the base of ceresin-80. Cables are manufactured per TU 4-61 and can run itself on the vertical and sharply inclined routes without the limitation of the value of a difference in the levels of the upper and lower points of the route of cable.

Table 2-11. Maximum permissible difference in the levels of two any points or end preparings with the separator of power cables with the paper insulation, saturated with oil-rosin composition.

(a) Характеристика кабелей	(b) Максимальная допустимая разность уровней, м
1. Кабели в алюминиевой оболочке на напряжение, кв: (1a)	
1 и 3	25
6	20
(1b) 1 кв с изоляцией из предварительно пропитанной бумаги	(1c) Не ограничивается
2. Кабели в свинцовой оболочке на напряжение, кв:	
(2a) 1 и 3 не бронированные	20
(2b) 1 и 3 бронированные	25
(2c) 6 и 10	15

Key: (a). Characteristic of cables. (b). Maximum permissible difference in levels, m. (1). Cables in aluminum shell to voltage, kV. (1A). and. (1b). 1 kV with the insulation from the pre-impregnated paper. (1c). It is not limited. (2). Cables in lead covering to voltage, kV. (2a). 1 and 3 not armored. (2b). 1 and 3 armored. (2c). 6 and 10.

Table 2-12. Fields of application of fundamental brands of power cables.

(a) Марки кабелей	(b) Назначение кабелей
ААБ, АВРБ, АНРБ, АВВБ, АПВБ, ААШВ, СБ, СРБ, ВРБ, НРБ, ВВБ-Т, ААВБ-Т	(1) Для прокладки в земле в траншее, если кабель не подвергается значительным растягивающим усилиям
ААБГ, АВРБГ, АНРБГ, ААШБГ, СБГ, СРБГ, ВРБГ, НРБГ, ВВБГ-Т, АВВБГ-Т	(2) Для прокладки внутри помещений, в каналах, туннелях, если кабель не подвергается значительным растягивающим усилиям
АЦАБ, ЦСБ	(3) Для прокладки в земле в траншее при крутонаклонных трассах, если кабель не подвергается значительным растягивающим усилиям
АЦАБГ, ЦСБГ	(4) Для прокладки внутри помещений, в каналах, туннелях, шахтах при вертикальных и крутонаклонных трассах, если кабель не подвергается значительным растягивающим усилиям

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Continuation table 2-12.

ЦСК	(5) Для прокладки в земле в траншее при крутонаклонных трассах при наличии значительных растягивающих усилий
ЦСКГ	(6) Для прокладки внутри помещений, в каналах, туннелях, шахтах при вертикальных и крутонаклонных трассах при наличии значительных растягивающих усилий
СК	(7) Для прокладки под водой
ААГ	(8) Для прокладки в помещениях, туннелях, каналах при отсутствии возможности механических повреждений в среде, нейтральной по отношению к алюминию
ААШа	(9) Для прокладки внутри помещений, в каналах, в земле в сельских местностях при отсутствии возможности механических воздействий
АЦАГ	(10) Для прокладки в помещениях, в каналах, туннелях при вертикальных и крутонаклонных трассах, если кабель не подвергается значительным растягивающим усилиям, в среде, нейтральной по отношению к алюминию
СРГ	(11) Для прокладки внутри помещений, в каналах, туннелях при отсутствии вибрации и механических воздействий на кабель в среде, нейтральной по отношению к свинцу
АСГТ, СГТ	(12) Для прокладки в трубах и блоках при отсутствии механических воздействий на кабель в среде, нейтральной по отношению к свинцу
ВВР, АВВГ-Т	(13) Для прокладки в блоках и трубах
АНРГ, НРГ, АПВГ	(14) Для прокладки внутри помещений, в каналах, туннелях при отсутствии механических воздействий на кабель
АВРГ, АВВГ, ВРГ	(15) Для прокладки внутри помещений, в каналах, туннелях при отсутствии механических воздействий на кабель и при наличии агрессивных сред (кислот, щелочей и др.)
(16) АВВГ, АПВГ облегченные для сельской местности	(17) Для прокладки внутри помещений, в каналах в земле, в траншеях, если кабель не подвергается растягивающим усилиям и внешним механическим воздействиям, превышающим предусмотренные инструкцией по прокладке кабелей

Key: (a). Cable make-ups. (b). Designation/purpose of cables. (1). For separator in earth/ground in trench, if cable does not undergo considerable stretching forces. (2). For separator indoors, in channels, tunnels, if cable does not undergo considerable stretching forces. (3). For separator in earth/ground in trench with sharply inclined routes, if cable does not undergo considerable stretching forces. (4). For separator indoors, in channels, tunnels, mines/shafts with vertical and sharply inclined routes, if cable does not undergo considerable stretching forces. (5). For separator in earth/ground in trench with sharply inclined routes in presence of considerable stretching forces. (6). For separator indoors, in channels, tunnels, mines/shafts with vertical and sharply inclined routes with presence of considerable stretching forces. (7). For separator under water. (8). For separator in locations, tunnels, channels in the absence of possibility of mechanical damage in medium, neutral with respect to aluminum. (9). For separator indoors, in channels, in earth/ground in rural localities in the absence of possibility of mechanical effects. (10). For separator in locations, in channels, tunnels with vertical and sharply inclined routes, if cable does not undergo considerable stretching forces, in medium, neutral with respect to aluminum. (11). For separator indoors, in channels, tunnels in the absence of vibration and mechanical effects on cable in medium, neutral with respect to lead. (12). For separator

in tubes and blocks in the absence of mechanical effects on cable to medium, neutral with respect to lead. (13). For separator in blocks and tubes. (14). For separator indoors, in channels, tunnels in the absence of mechanical effects on cable. (15). For separator indoors, in channels, tunnels in the absence of mechanical effects on cable and in presence of agressive media (acids, alkalis, etc.). (16). facilitated for rural locality. (17). For separator indoors, in channels in earth/ground, in trenches, if cable does not undergo stretching forces and external mechanical effects, exceeding those called for by instruction on cable laying.

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The construction lengths of cables with the paper insulation in the lead covering to 10 kV by the section: to 70 mm² - 300 m, 95 and 120 mm² - 250 m, are more than 150 mm² - 200 m.

2-4. Wiring and cables in the dangerously explosive locations.

In the dangerously explosive locations of the classes of a V- I and V- Ia for the power and lighting systems must be used the wires and cables with the copper veins/strands; separator in these locations of wires and cables with the aluminum veins/strands is not allowed/assumed. In the dangerously explosive locations of all

remaining classes is allowed/assumed the use/application of wires and cables with the aluminum veins/strands in the presence the condition of fulfilling of connections and termination by soldering or welding and in apparatuses and instruments, to which they are connected, special contact terminals/grippers.

For the power and lighting systems to 1000 V in the dangerously explosive locations can be used the cables with the paper insulation, cables and wires with rubber, polychlorovinyl or equivalent it by insulation. In this case the wires and unarmoured cables in the locations of the classes of a V- I and a V-II, and also in the power networks/grids in places of class V-Ia must run itself in the steel tubes. The surface work of unarmoured cables is allowed/assumed in the power and lighting systems not above 380 V, also, in the absence of the possibility of the mechanical and chemical effects in the locations of classes V-Ib and V Ia, or in the lighting networks/grids in the locations of class V-Ia. In all remaining cases in the dangerously explosive locations it is opened the laid cables with the rubber or paper insulation to 1000 V and above they must be armored and not have external deposits from the fuels.

Table 2-13. Construction lengths of power cables with the paper insulation in the aluminum shell.

(1) Номинальное сечение основной жилы, мм²	(2) Номинальное напряжение			
	(3) до 1 кв		(6) 3 кв	6 кв
	(4) трехжильные	(5) четырехжильные		
(7) Строительная длина, м				
6	—	—	525	—
10	—	—	475	325
16	—	—	375	300
25	—	—	350	300
35	400	350	325	250
50	350	300	300	200
70	300	225	225	175
95	250	200	200	—
120	225	—	—	—

Key: (1). Nominal section of fundamental vein/strand, mm². (2). Nominal voltage. (3). to 1 kV. (4). three-core. (5). four-strand. (6). kV. (7). Construction length, m.

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The wire insulation and cables must correspond to nominal line voltage, but be not below 500 V.

Electric wirings in the steel tubes must test to density of connections with overpressure 2.5 atm(tech) for the locations of the class V-I and 0.5 atm(tech) for places of classes V-Ia, V-II and V-IIa. in this case during 3-5 min the pressure must not decrease by

more than 10-20o/o.

Surface work dangerously explosive indoors of the uninsulated conductors, including trollies for the taps/cranes, is forbidden, with exception of the locations of classes V-Ia and V-Ib, for which is allowed/assumed the use/application of the uninsulated copper and aluminum conductors under the condition of their separator in accordance with § VII-3-64 PUE.

Is allowed/assumed the separator of armored cables in the channels under the condition of charging by their sand for the locations of the classes of a V- I and B-Ia, that contain combustible vapors or gases with the specific gravity/weight more than 0.8 with respect to the air, and for the locations of the class V-II. In this case the permissible constant loads on the cables must be accepted on the appropriate tables chapters of 1-3 PUE as for the cables, laid in air, with consideration the correction factor to a number of working cables in Tables 4-21.

Is allowed/assumed cable laying in the tunnels and the blocks, isolated/insulated from the production locations by the incombustible partitions/baffles, under the condition of the device/equipment of fairleads in accordance with the requirements p. 1 § VII-3-53 PUE.

In the locations of the class V-I in the two-wire circuits with the neutral conductor they must be shielded from the excess currents both phase and neutral conductor with the installation for the simultaneous cutoff/disconnection of the phase and neutral conductors of two-pole switch. In this case for the grounding must be laid the third wire.

In the dangerously explosive locations the neutral conductors must have insulation, equivalent with the insulation of phase conductors, and must run itself in the general/common/total shell or the tube with the phase conductors.

With the separator in the dangerously explosive placements of insulated wires and cables in the steel tubes of the section of wires of cores of cables they must not be below:

copper wires and cables:

for the lighting systems ... 1.5 mm².

for the power networks/grids ... 2.5 mm².

Aluminum wires and cables:

for lighting networks/grids ... 2.5 mm^2.

for the power networks/grids ... 4 mm^2.

The use/application of aluminum wires for the charging of illuminating lamps is not allowed/assumed.

In the placements of class V-Ib and the external installations of class V-Id the selection of sections and the protection of wires and cables from the currents of overloading and short circuits must be conducted as for the nonexplosive locations.

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Section Three

DETERMINATION OF CALCULATED ELECTRICAL LCADS.

3.1. Design loads of industrial enterprises.

Design loads for the industrial enterprises are located on the basis of "indications regarding the electrical lcads in the industrial installations".

For electrical netwcrks by design lcads are the greatest possible loads the duraticn nct less than 30 min.

The value of design load depends on a number and the installed power of electrical receivers, character of production and degree cf the automation of producticn process.

1. Nominal (established/installed) power of electrical receivers.

Ncminal active power for cne electrical receiver is determined from the formulas:

for the receivers of illumination and electric motors during the continuous duty

$$p_у = P_н, \text{ kW}; \qquad (3-1)$$

for the electric motors of intermittent duty

$$p_у = \sqrt{ПВ_н}\, P_{н.н}, \text{ kW}; \qquad (3-2)$$

for the transformers of the electric furnaces

$$p_у = S_н \cos \varphi_н, \text{ kW}; \qquad (3-3)$$

for the transformers of welding sets and apparatuses and of arc welding transformers of manual welding

$$p_у = \sqrt{ПВ_н}\, S_н \cos \varphi_{н.}, \text{ kW}, \qquad (3-4)$$

where $P_н$ - nominal power of the receiver of illumination or nominal (certified/rating) power of electric motor for the continuous duty, kW;

$ПВ_н$ - nominal (certified/rating) duration of inclusion/connection, rel. un.;

$P_{п.н}$ - certified/rating power of electric motor with the nominal relative duration of inclusion/connection, kW;

$S_н$ - certified/rating power of transformer, kVA;

$\cos\varphi_н$ - coefficient of power of electric furnace, welding set or arc welding transformer under the nominal conditions.

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The nominal power of the group of electrical receivers is defined as the sum of the nominal power of all electrical receivers:

$$P_у = \sum_1^n p_у, \quad kW, \qquad (3-5)$$

where $p_у$ - nominal power of electrical receiver, kW;

n - total number of electrical receivers in the group.

2. Design loads.

For one electrical receiver calculated active power takes as the equal to:

during the continuous duty

$$P=p_{T},\ kW \qquad (3-6)$$

during the intermittent duty

$$P=\frac{p_{T}}{0,875}=1,14\,p_{T},\ kW, \qquad (3-7)$$

where p_T - nominal power of electrical receiver, kW.

During the intermittent duty of electrical receiver the installed power must be given to the continuous duty on one of formulas (3-2) or (3-4).

The calculated reactive power of one electrical receiver is determined from the expression

$$Q=P\,tg\varphi,\ kilovar, \qquad (3-8)$$

where φ - phase angle of the current of electrical receiver during the mode/conditions of design load.

For the group of electrical receivers by a number to 3 inclusively active and reactive rated powers are defined as the sums of the respectively active and reactive load of electrical receivers of group.

During the tentative calculations is allowed/assumed to determine the calculated active power of one or several groups of electrical receivers according to the formula

$$P=\sum_{1}^{n} K_c P_y,\ \text{kW}, \qquad (3\text{-}9)$$

where K_c and P_y - respectively average value of the coefficient of demand [1] and the installed power of the group of the uniform electrical receivers;

n - total number of groups of electrical receivers.

FOOTNOTE [1]. The coefficient of demand is called the ratio of design load to nominal. ENDFOOTNOTE.

Reactive rated power can be determined from the expression

$$Q = P \operatorname{tg} \varphi, \text{ kilovar,} \qquad (3\text{-}10)$$

where φ - phase angle of summed current of the entire group of electrical receivers for the mode/conditions of design load.

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The average/mean values of the coefficient of the demand of power load for some productions are given in Tables 3-1 and 3-2.

The coefficient of the demand of the lighting load of industrial enterprises and relating to them auxiliary and everyday equipment is accepted on Tables 3-3.

In general coefficient of the demand of the group of the electrical receivers of industrial enterprise is defined as the product of coefficients of use ($K_и$) and maximum ($K_м$):

$$K_c = K_и K_м. \qquad (3\text{-}11)$$

The coefficients of use and maximum of the group of electrical receivers respectively are equal to:

$$K_и = \frac{P_{см}}{P_y}; \qquad (3\text{-}12)$$

$$K_м = \frac{P}{P_{см}}. \qquad (3\text{-}13)$$

where $P_{см}$ - average resistive load of the group of electrical

receivers in question for the most loaded exchange of enterprise kW [1];

P and P_y - Respectively the calculated and nominal active of the power of the same group of electrical receivers, kW.

FOOTNOTE [1]. It is determined by the division of rate of discharge of electric power for the exchange by the duration of exchange in the hours. ENDFOOTNOTE.

The values of coefficients of use in the dependence on the type of the given mechanisms and character of production are given in Table 3-1.

The values of the coefficient of use for several groups of electrical receivers with the different values of the coefficient of use are determined from formula (3-12), in which as $P_{см}$ should be understood the sum of medium loads for the most loaded exchange for all groups of the electrical receivers:

$$P_{см} = \sum_{1}^{n} K_и p_у,\ квт. \quad (3\text{-}14)$$

Coefficient of the demand of the group of electrical receivers for the tentative calculations can be accepted in the dependence on the coefficient of use in Tables 3-4.

3. Determination of coefficient of maximum.

During calculations at the stage of technical project or working drawings design loads are determined with consideration the coefficient of the maximum [2] whose value depends on the coefficient of use and effective number of electrical receivers.

FOOTNOTE [2]. The coefficient of maximum is called the ratio of maximum rated load to the medium load for the most loaded exchange. ENDFOOTNOTE.

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Table 3-1. Values of calculated coefficients for different groups of mechanisms.

(a) Наименование механизмов и аппаратов	(b) Коэффициент		
	(c) использования	(d) мощности	(e) спроса
(1) Горно-обогатительные комбинаты и аглофабрики			
(2) Насосы, вентиляторы, компрессоры, газодувки, эксгаустеры			
(3) Насосы водяные	0,7—0,8	0,8—0,85	0,75—0,9
(4) Насосы песковые	0,9	0,8	0,91
(5) Вакуум-насосы	0,95	0,85	0,95
(6) Вентиляторы	0,6—0,8	0,75—0,85	—
(7) Вентиляторы высокого давления для аглофабрик	0,75	0,85	—
(8) Вентиляторы к дробилкам	0,4—0,5	0,7—0,75	—
(9) Аглоэксгаустеры (газодувки)	0,5—0,6	0,6—0,7	0,6—0,7
(10) Механизмы дробления и измельчения			
(11) Дробилки молотковые	0,8	0,85	—
(12) Дробилки конусные	0,6—0,7	0,75—0,8	—
(13) Дробилки четырехвалковые	0,9	0,9	—
(14) Мельницы шаровые	0,8	0,8	—
(15) Мельницы стержневые	0,7	0,75	—
(16) Грохоты	0,5—0,6	0,6—0,7	—
(17) Механизмы непрерывного транспорта			
(18) Транспортеры ленточные свыше 170 *квт*	0,5—0,6	0,7—0,8	—
(19) Транспортеры ленточные до 170 *квт*	0,5—0,6	0,65—0,75	—
(20) Конвейеры до 10 *квт*	0,4—0,5	0,6—0,7	—
(21) Конвейеры свыше 10 *квт*	0,55—0,75	0,7—0,8	—
(22) Конвейеры корпуса крупного дробления	0,5—0,65	0,6—0,85	—
(23) Питатели пластинчатые, тарельчатые, барабанные и дисковые	0,3—0,4	0,5—0,6	—
(24) Элеваторы, шнеки	0,6	0,7	—
(25) Механизмы фильтрации и обогащения			
(26) Сгустители	0,7	0,8	—
(27) Барабаны смесительные	0,6—0,7	0,8	—
(28) Чашевые охладители	0,7	0,85	—
(29) Столы концентрационные, чаны, баки концентрационные и реагентные	0,6	0,7	—
(30) Сушильные барабаны и сепараторы	0,6	0,7	—

Table 3-1 Continued.

(31) Классификаторы спиральные и реечные	0,65	0,8	—
(32) Флотационные машины	0,9	0,8	—
(33) Электрофильтры	0,4	0,87	—
(34) Магнитные сепараторы индивидуальные	0,4	—	—
(35) Двигатель-генераторы	0,7	0,8	—
(36) Вакуум-фильтры (лента, барабаны)	0,3	0,4	—
(37) Вагоноопрокидыватели	0,6	0,5	—
(38) Грейферные краны	0,2	0,6	—
(39) Коксохимические заводы и цехи			
(40) Транспортеры	0,3—0,7	0,4—0,85	0,5—0,8
(41) Транспортеры катучие	0,3	0,75	0,4
(42) Питатели пластинчатые и ленточные	0,45	0,75	0,6
(43) Дробилки молотковые	0,8	0,8	0,9
(44) Дозировочные столы	0,25	0,5	0,35
(45) Штабелеры	0,16	0,6—0,75	0,35
(46) Углеперегружатели	0,14	0,5	0,2
(47) Коксовыталкиватели	0,1	0,75	0,2
(48) Загрузочные вагоны	0,3	0,6	0,4
(49) Двересъемные машины	0,3	0,7	0,25
(50) Электровозы тушильных вагонов	0,15	0,75	0,2
(51) Скиповые подъемники	0,05	0,5	0,3
(52) Кабестаны	0,5	0,7	0,55
(53) Вагоноопрокидыватели	0,3	0,6	0,35
(54) Металлургические заводы и цехи черной и цветной металлургии			
(55) Насосы, вентиляторы, компрессоры			
(56) Насосы водяные	0,7—0,8	0,8—0,85	0,8
(57) Насосы питательные мартеновского цеха	0,9	0,9	0,95
(58) Дымососы мартеновского цеха	0,9	0,9	0,95
(59) Вентиляторы доменного цеха	0,7—0,95	0,7—0,87	—
(60) Вентиляторы газовых горелок	0,65	0,85	—
(61) Вентиляторы прокатных цехов	0,6—0,75	0,75—0,9	0,7—0,9
(62) Вентиляторы принудительного дутья	0,5—0,7	0,7—0,8	0,6—0,8

Table 3-1 continued.

(63) Вентиляторы машинных залов	0,65	0,8	—
(64) Компрессоры	0,65	0,8	0,8
(65) Механизмы непрерывного транспорта			
(66) Конвейеры	0,35	0,7	0,55
(67) Краны различных назначений			
(68) Краны рудного двора	0,35	0,7	0,5
(69) Грейферные краны	0,35	—	—
(70) Магнитные краны	0,5	—	—
(71) Краны разные	0,14—0,3	0,6—0,7	0,22—0,36
(72) Термические и сварочные электроприемники			
(73) Печи сопротивления с непрерывной загрузкой	0,8	1,0	0,85
(74) Печи сопротивления с периодической загрузкой	0,6	1,0	0,7
(75) Дуговые сталеплавильные печи емкостью 3—10 *т* с автоматическим регулированием электродов:			
(76) для качественных сталей с механизированной загрузкой	0,75	0,9	—
(77) для качественных сталей без механизированной загрузки	0,6	0,87	—
(78) для фасонного литья с механизированной загрузкой	0,75	0,9	—
(79) для фасонного литья без механизированной загрузки	0,65	0,87	—
(80) Дуговые сталеплавильные печи емкостью 0,5—1,5 *т* для фасонного литья во вспомогательных цехах с автоматическим регулированием электродов	0,5	0,8	—
(81) Дуговые печи для цветного металла (медных сплавов) емкостью 0,25—0,5 *т* с ручным регулированием электродов	0,7	0,75	0,78

Table 3-1 Continued.

(82) Руднотермические печи с трехфазными трансформаторами 6; 7,5 и 9 *Мва* . .	0,9	0,9	—
(83) Сушильные шкафы	0,8	1,0	—
(84) Мелкие нагревательные приборы	0,6	1,0	0,7
(85) Сварочные трансформаторы для дуговой электросварки	0,2	0,4	0,3
(86) Сварочные трансформаторы для автоматической сварки	0,4	0,5	—
(87) **Машиностроительная и металлообрабатывающая отрасли промышленности**			
(88) Металлорежущие станки мелкосерийного производства с нормальным режимом работы — мелкие токарные, строгальные, долбежные, фрезерные, сверлильные, карусельные, точильные и т. п.	0,12—0,14	0,4—0,5	0,14—0,16
(89) То же при крупносерийном производстве	0,16	0,5—0,6	0,2
(90) То же при тяжелом режиме работы: штамповочные прессы, автоматы, револьверные, обдирочные, зуборезные, а также крупные токарные, строгальные, фрезерные, карусельные, расточные станки . .	0,17	0,65	0,25
(91) То же с особо тяжелым режимом работы: приводы молотов, ковочных машин, волочильных станов, очистных барабанов, бегунов и пр.	0,2—0,24	0,65	0,35—0,4
(92) Переносный электроинструмент	0,06	0,5	0,1
(93) Вентиляторы, эксгаустеры, санитарно-гигиеническая вентиляция	0,6—0,65	0,8	0,65—0,7
(94) Насосы, компрессоры, дизель-генераторы	0,7	0,85	0,75

Table 3-1 continued.

(95) Краны, тельферы при ПВ-25%	0,1	0,5	0,2
(96) То же при ПВ-40%	0,2	0,5	0,32
(97) Элеваторы, транспортеры, шнеки, конвейеры несблокированные	0,4	0,75	0,5
(98) То же сблокированные	0,55	0,75	0,65
(99) Сварочные трансформаторы дуговой электросварки	0,2	0,4	0,3
(100) Однопостовые сварочные двигатель-генераторы	0,3	0,6	0,35
(101) Многопостовые сварочные двигатель-генераторы	0,5	0,7	0,7
(102) Сварочные машины шовные	0,2—0,5	0,7	—
(103) То же стыковые и точечные	0,2—0,25	0,6	—
(104) Сварочные дуговые автоматы типа АДС	0,35	0,5	0,5
(105) Печи сопротивления, сушильные шкафы, нагревательные приборы	0,75—0,8	0,95	0,75—0,9
(106) Печи сопротивления с неавтоматической загрузкой изделий	0,5	0,95	0,8
(107) Индукционные печи низкой частоты	—	0,35	0,8
(108) Двигатель-генераторы индукционных печей высокой частоты	—	0,8	0,8
(109) Ламповые генераторы индукционных печей высокой частоты	—	0,65	0,8
(110) Многошпиндельные автоматы механических цехов для деталей из прутков	0,2	0,5—0,6	0,23

(111) Строительная промышленность

(112) Бетоноукладчики	0,15	0,6	0,2—0,3
(113) Автоматические станки для правки и резки проволоки	0,15	0,6	0,2—0,4
(114) Формовочные машины	0,15	0,6	0,2—0,25
(115) Конвейеры	0,15	0,5	0,17—0,2
(116) Рольганги	0,1	0,5	0,1
(117) Земснаряды	0,26—0,93	0,69—0,78	—
(118) Экскаваторы с электроприводом	—	0,5—0,6	0,4—0,6
(119) Растворные узлы	—	0,5—0,6	0,4—0,6
(120) Краны башенные и портальные	—	0,5	0,2
(121) Трансформаторный электропрогрев бетона, отогрев грунта и трубопроводов	—	0,75	0,7
(122) Однопостовые двигатель-генераторы для сварки	—	0,6	0,35
(123) Сварочные трансформаторы	0,2	0,4	0,3
(124) Переносные механизмы	—	0,45	0,1

Key: (A). Designation cf mechanisms and apparatuses. (b). Coefficient. (c). use [1].

FOOTNOTE [1]. The coefficient of the use of a maximum resistive load is called the ratio of average resistive load for the most loaded exchange of enterprise tc the nominal power. ENDFOOTNOTE.

(d). power. (e). demand. (1). Ore-dressing combines and sintering plants. (2). Pumps, fans, compressors, gas blowers, exhausters. (3). Pumps (water. (4). Pumps (sand. (5). Vacuum pumps. (6). Fans. (7). Air extractors for sintering plant. (8). Fans to crushers. (9). Agglomerated exhausters gas blowers . (10). Mechanisms of fragmentation and grinding. (11). Crushers (hammer. (12). Crushers (conical. (13). Crushers (double-roll. (14). Mills (spherical. (15). Mills (rod. (16). Crashes/gratings. (17). Mechanisms of continuous transport. (18). Transporters strip/tape are more than 170 KVM. (19). Transporters strip/tape to 170 KVM. (20). Conveyors to 10 KVM. (21). Conveyors are more than 10 KVM. (22). Conveyors of housing of coarse crushing. (23). Feeders lamellar, plate, drum and disk. (24). Elevators, worm conveyors. (25). Mechanisms of filtration and enrichment. (26). Thickeners. (27). Drums (mixing. (28). Cup coolants. (29). Tables concentration, vats, tanks concentration and reagent. (30). Drying drums and separators. (31). Classifiers (spiral

and rack). (32). Flotation machines. (33). Electric filters. (34). Magnetic separators individual. (35). Dynamometers. (36). Vacuum filters (tape, drums). (37). Car dumpers. (38). Bucket cranes. (39). coke-chemical plants and shops. (40). Transporters. (41). Transporters (rolling. (42). Feeders (lamellar and strip/tape). (43). Crushers (hammer. (44). Dosage tables. (45). Stackers. (46). Coal loaders. (47). Coke extractors. (48). Charging cars. (49). Door extractor, machines. (50). Electric locomotives of extinguishing cars. (51). Skip hoists. (52). Capstans. (53). Car dumpers. (54). Metallurgical plants and shops of ferrous and nonferrous metallurgy. (55). Pumps, fans, compressors. (56). Pumps (water. (57). Pumps (feed of open-hearth shop). (58). Exhaust fans of open-hearth shop. (59). Fans of blast-furnace plant. (60). Fans of gas burners. (61). Fans of rolling departments. (62). Positive fans. (63). Fans of machine rooms. (64). Compressors. (65). Mechanisms of continuous transport. (66). Conveyors. (67). Taps/cranes of different designations/purposes. (68). Taps/cranes of ore yard. (69). Bucket cranes. (70). Magnet-handlings crane. (71). Taps/cranes (different. (72). Thermal and welding electrical receivers. (73). Resistance furnaces with continuous charging. (74). Resistance furnaces with periodic duty. (75). Arc steel smelting furnaces in capacity/capacitance 3-10 m with automatic control of electrodes: (76). for fine steel with mechanized charging. (77). for fine steel without mechanized charging. (78). for mold casting with mechanized

charging. (79). for mold casting without mechanized charging. (80). Arc steel smelting furnaces in capacity/capacitance 0.5-1.6 m for mold casting in auxiliary shops with automatic control of electrodes. (81). Arc furnaces for nonferrous metal (copper alloys) in capacity/capacitance 0.25-0.5 m with manual control of electrodes. (82). Ore-thermal furnaces with three-phase transformers 6; 7.5; even 9 MVA. (83). Cabinet driers. (84). Fine/small heaters. (85). Arc welding transformers for electric arc welding. (86). Arc welding transformers for automatic welding. (87). Machine-building and metalworking branches of industry. (88). Cutting metal machine tools small-scale productions with normal mode of work - fine/small turning, planing, mortising, milling, boring, revolving, grinding, etc. (89). Same in large-scale production. (90). Then during arduous duty: stamping machines, automatic machines, revolver, abrasive, gear-cutting, and also large/coarse turning, planing, milling, revolving, boring machines. (91). Then with extra-heavy operating mode: drives of hammers, forging machines, draw plate mills, tumbling barrels, edge runner mills and so forth, etc. (92). Movable power tool. (93). Fans, exhausters, health and hygiene ventilation. (94). Pumps, compressors, diesel generators. (95). Taps/cranes, telphers with PV-25o/o. (96). Same with PV-40o/o. (97). Elevators, transporters, worm conveyors, conveyors nonblocked/interlocked (98). Same blocked/interlocked (99). Arc welding transformers of electric arc welding. (100). One-position welding engine-generators. (101).

Multioperator welding dynamotors. (102). Welding sets seam. (103). Same joint and point. (104). Welding automatic heads of type ADS. (105). Resistance furnaces, cabinet driers, heaters. (106). Resistance furnaces with nonautomatic charging of articles. (107). Induction furnaces of low frequency. (108). Dynamotors of induction furnaces of high frequency. (109). Vacuum-tube oscillators of induction furnaces of high frequency. (110). Multihead automatic machines of machine shops for parts from bars. (111). Construction industry. (112). Concrete-packers. (113). Automatic machine tools for straightening and cutting wire. (114). Molding machines. (115). Conveyors. (116). Roller conveyors. (117). Dredgers. (118). Excavators with electric drive. (119). Solution units. (120). Taps/cranes (tower and portal). (121). Transformer electric heating of concrete, warming soil and conduits/manifolds. (122). One-position dynamotors for welding. (123). Arc welding transformers. (124). Movable mechanisms.

Note. At several values of the coefficients of use and power one should take the highest values.

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Under an effective number of group of electrical receivers with different installed power and different operating modes is understood

such number of receivers, identical according to the power and on the uniform ones under the conditions of work, which they provide the same value of design load, as the group of different under power and conditions of work electrical receivers in question.

An in general effective number of electrical receivers can be found from the expression

$$n_э = \frac{\left(\sum_{1}^{n} p_у\right)^2}{\sum_{1}^{n} p_у^2}. \qquad (3\text{-}15)$$

An effective number of electrical receivers can be accepted by the equal to their actual number in the following cases:

a) when the power of all receivers it is identical;

b) with the coefficient of use $K_и > 0.8$;

c) when they are made the indicated in Table 3-5 relationships/ratios between the coefficient of use and the value of the relation, equal to:

$$m = \frac{p_{у.макс}}{p_{у.мин}}, \qquad (3\text{-}16)$$

where $p_{у\,макс}$ and $p_{у\,мин}$ - with respect nominal active power of the greatest and smallest electrical receivers in group, kW.

During determination $P_{y.max}$ must be excluded the finest/smallest electrical receivers whose total power does not exceed 5o/o of power of the entire group of receivers.

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Table 3-2. Control indices of the loads of some branches of industry.

(a) Наименование отраслей промышленности	(b) Общезаводской коэффициент спроса	(c) Средневзвешенный коэффициент мощности	(d) Коэффициент мощности при максимальной нагрузке	(e) Годовое число часов использования максимума¹	
				(f) активной нагрузки	(g) реактивной нагрузки
(1) Химические заводы	0,28—0,5	0,773	0,82	6 200	7 000
(2) Анилинокрасочные заводы	0,33—0,35	—	0,7	7 100	—
(3) Нефтеперегонные заводы	0,34—0,37	—	0,9	7 100	—
(4) Заводы тяжелого машиностроения	0,22	0,62	0,77	3 770	4 840
(5) Заводы станкостроения	0,23	0,65	0,68	4 345	4 750
(6) Инструментальные заводы	0,22	0,63	0,69	4 140	4 960
(7) Заводы шарикоподшипников	0,4	0,8	0,83	5 300	6 130
(8) Заводы подъемно-транспортного оборудования	0,19	0,69	0,75	3 330	3 880
(9) Автотракторные заводы	0,22	0,78	0,79	4 960	5 240
(10) Сельскохозяйственное машиностроение	0,21	0,85	0,79	5 330	4 220
(11) Приборостроение	0,32	0,75	0,79	3 080	3 180
(12) Авторемонтные заводы	0,2	0,76	0,65	4 370	3 200
(13) Вагоноремонтные заводы	0,22	0,72	0,69	3 560	3 660
(14) Электротехнические заводы	0,31	0,64	0,82	4 280	6 420
(15) Азотнотуковые заводы	0,6—0,65	—	—	7 000—8 000	—
(16) Различные металлообрабатывающие заводы	0,3	0,88	0,87	4 355	5 880

Key: (a). Designation of the branches of industry (b). All-factory the coefficient of demand. (c). Weighted mean power factor. (d). Power factor with peak load. (e). Annual total hours of utilization of maximum [1].

FOOTNOTE [1]. It is determined by the division of the annual consumption of electric power into the peak load. ENDFOOTNOTE.

(f). resistive load. (g). reactive load. (1). Chemical plants. (2).

Aniline dye plants. (3). Petroleum refineries. (4). Heavy Machine Building Plants. (5). Plants of machine-tool construction. (6). Tool Plants. (7). Plants of ball bearings. (8). Plants of lifting-transporting equipment. (9). Tractor plants. (10). Agricultural machine-building. (11). Instrument manufacture. (12). Motor vehicle repair plants. (13). Car-repair plants. (14). Electrical plants. (15). Nitric manure plants. (16). Different metal working plants.

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When the conditions indicated are not satisfied, an effective number of electrical receivers is determined in depending on values p_* and n_*, computed from the formulas [1]

$$p_* = \frac{\sum_1^{n_1} p_{T1}}{\sum_1^{n} p_T} \qquad (3\text{-}17)$$

and

$$n_* = \frac{n_1}{n}, \qquad (3\text{-}18)$$

where n - total number of electrical receivers of the group;

$\sum_1^n p_T$ - sum of the nominal power of entire group, kW;

n_1 - number of receivers in the group, the nominal power of each of

which more or is equal tc tne nalf the ncminal power of most powerful/thickest receiver in the group;

$\sum_{1}^{n_1} P_n$ - sum of the nominal power of these receivers, kW.

Table 3-3. Coefficient of the demand of the lighting load of industrial enterprises and servicing constructions K_c

(a) Назначение помещения	(b) Коэффициент спроса
(1) Мелкие производственные здания и торговые помещения	1,0
(2) Производственные здания, состоящие из отдельных крупных пролетов	0,95
(3) Производственные здания, состоящие из отдельных помещений	0,85
(4) Конторско-бытовые и лабораторные здания	0,8
(5) Складские здания, электрические подстанции	0,6
(6) Аварийное и наружное освещение	1,0
(7) Линии групповой сети и линии, питающие осветительные щитки	1,0

Key: (a). Destination of location. (b). Coefficient of demand. (1). Fine/small production buildings and commercial locations. (2). Production buildings, which consist of separate large/coarse flights/spans. (3). production buildings, which consist of separate locations. (4). office- everyday and laboratory buildings. (5). Storage buildings, electrical substations. (6). Emergency and exterior lighting. (7). lines of group network/grid and line, that feeds lighting panels.

Table 3-4. Values of the coefficient of demand K_c in depending on the coefficient of use $K_и$

$K_и$	0.4	0.5	0.6	0.7	0.8	0.9
K_c	0,5	0,6	0,65—0,7	0,75—0,8	0,85—0,9	0,92—0,95

Table 3-5. The relationships/ratios between the coefficient of use $K_и$ and the value of relation m, in which is allowed/assumed to accept $n_э=n$

$K_и$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
$m<$	2.5	3.0	3.5	4.0	5.0	6.5	8.0	10.0

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The fine/small electrical receivers whose total power does not exceed 5c/o of nominal power of all electrical receivers, during determination $\sum_1^n p_у$ are not considered.

In depending on sublimity p_* and n_* through Tables 3-6 is found the value of the relative value of an effective number of electrical receivers:

$$n_{*э}=\frac{n_э}{n} \quad (3\text{-}19)$$

and determine an effective number of receivers by the multiplication of obtained value $n_{*э}$ for the total number of electrical receivers the groups:

$$n_э=n_{*э}n. \quad (3\text{-}20)$$

In depending on the coefficient of use $K_и$ and effective number of receivers $n_э$ in Tables 3-7 is determined the coefficient of maximum $K_м$.

The amounts of the calculated active and reactive power of the group of electrical receivers it is determined from the formulas:

$$P = K_u P_{cm},\ kW$$
$$Q = P \operatorname{tg} \varphi,\ \text{Kilovar}$$

where P_{cm} - average/mean active power for the group of electrical receivers for most loaded exchange, kW;

tg ϕ - corresponds to the characteristic for this group of electrical receivers value of phase node in the mode/conditions of maximum active power.

Complete rated power is determined from the expression,

$$S = \sqrt{P^2 + Q^2},\ kVA \qquad (3\text{-}23)$$

calculated current - according to the formula

$$I = \frac{S}{\sqrt{3}\, U_n},\ a, \qquad (3\text{-}24)$$

where U_n - nominal of the line voltage, kV.

Power factor during the mode/conditions of design load is equal to:

$$\cos \varphi = \frac{P}{S}. \qquad (3\text{-}25)$$

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Table 3-6. Relative values of an effective number of electrical receivers $n_э = \frac{n_э}{n}$ in depending on $n_* = \frac{n_1}{n}$

$$\text{и}\; p_* = \frac{\sum_1^{n_1} p_{н1}}{\sum_1^{n} p_н}$$

$n_* = \frac{n_1}{n}$	p_*																		
	1	0.95	0.9	0.85	0.8	0.75	0.7	0.65	0.6	0.55	0.5	0.45	0.4	0.35	0.3	0.25	0.2	0.15	0.1
0,005	0,005	0,005	0.006	0,007	0.007	0,009	0.01	0,011	0,013	0,016	0,019	0,024	0,03	0,039	0.051	0,073	0,11	0,18	0,34
0.01	0,009	0,011	0.012	0,013	0.015	0.017	0,019	0,023	0,026	0,031	0,037	0,047	0,059	0,076	0.1	0,14	0,20	0,32	0,52
0,02	0,02	0,02	0,02	0,03	0,03	0,03	0,04	0,04	0,05	0,06	0,07	0,09	0,11	0,14	0,19	0,26	0,36	0,51	0,71
0,03	0,03	0,03	0,04	0,04	0,04	0,05	0,06	0,07	0,08	0,09	0,11	0,13	0,16	0,21	0,27	0,36	0,48	0,64	0,81
0,04	0,04	0,04	0,05	0,05	0,06	0,07	0,08	0,09	0,1	0,12	0,15	0,18	0,22	0,27	0,34	0,44	0,57	0,72	0,86
0,05	0,05	0,05	0,06	0,07	0,07	0,08	0,1	0,11	0,13	0,15	0,18	0,22	0,26	0,33	0,41	0,51	0,64	0,79	0,9
0,06	0,06	0,06	0,07	0,08	0,09	0,1	0,12	0,13	0,16	0,18	0,21	0,26	0,31	0,38	0,47	0,58	0,7	0,83	0,92
0,08	0,08	0,08	0,09	0,11	0,12	0,13	0,15	0,17	0,2	0,24	0,28	0,33	0,4	0,48	0,57	0,68	0,79	0,89	0,94
0,1	0,09	0,1	0,12	0,13	0,15	0,17	0,19	0,22	0,25	0,29	0,34	0,4	0,47	0,56	0,66	0,76	0,85	0,92	0,95
0,15	0,14	0,16	0,17	0,2	0,23	0,25	0,28	0,32	0,37	0,42	0,48	0,56	0,67	0,72	0,8	0,88	0,93	0,95	—

Table 3-6 Continued.

$n=\frac{n_1}{n}$	ξ																		
	1	0,95	0,9	0,85	0,8	0,75	0,7	0,65	0,6	0,55	0,5	0,45	0,4	0,35	0,3	0,25	0,2	0,15	0,1
0,2	0,19	0,21	0,23	0,26	0,29	0,33	0,37	0,42	0,47	0,54	0,64	0,69	0,76	0,83	0,89	0,93	0,95	—	—
0,25	0,24	0,26	0,29	0,32	0,36	0,41	0,45	0,51	0,57	0,64	0,71	0,78	0,85	0,9	0,93	0,95	—	—	—
0,3	0,29	0,32	0,35	0,39	0,43	0,48	0,53	0,6	0,66	0,73	0,8	0,86	0,9	0,94	0,95	—	—	—	—
0,35	0,33	0,37	0,41	0,45	0,5	0,56	0,62	0,68	0,74	0,81	0,86	0,91	0,94	0,95	—	—	—	—	—
0,4	0,38	0,42	0,47	0,52	0,57	0,63	0,69	0,75	0,81	0,86	0,91	0,93	0,95	—	—	—	—	—	—
0,45	0,43	0,47	0,52	0,58	0,64	0,7	0,76	0,81	0,87	0,91	0,93	0,95	—	—	—	—	—	—	—
0,5	0,48	0,53	0,58	0,64	0,7	0,76	0,82	0,89	0,91	0,94	0,95	—	—	—	—	—	—	—	—
0,55	0,52	0,57	0,63	0,69	0,75	0,82	0,87	0,91	0,94	0,95	—	—	—	—	—	—	—	—	—
0,6	0,57	0,63	0,69	0,75	0,81	0,87	0,91	0,94	0,95	—	—	—	—	—	—	—	—	—	—
0,65	0,62	0,68	0,74	0,81	0,86	0,91	0,94	0,95	—	—	—	—	—	—	—	—	—	—	—
0,7	0,66	0,73	0,8	0,86	0,9	0,94	0,95	—	—	—	—	—	—	—	—	—	—	—	—
0,75	0,71	0,78	0,85	0,9	0,93	0,95	—	—	—	—	—	—	—	—	—	—	—	—	—
0,8	0,76	0,83	0,89	0,94	0,95	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0,85	0,8	0,88	0,93	0,95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0,9	0,85	0,92	0,95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	0,95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: For intermediate values ξ and n, one should take nearest low values ξ.

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During the determination of an effective number of electrical receivers for a large number that feeding of lines, several transformer points, distributive substations and the like is allowed/assumed to apply the simplified calculation procedure which consists of the following.

For the individual lines or the substations, for which earlier were determined the values of nominal power and effective number of electrical receivers, are calculated the power of conditional electrical receivers from the formula

$$p'_{y} = \frac{P_{y}}{n_{э}}, \text{ kW}, \qquad (3\text{-}26)$$

where P_{y} and $n_{э}$ - respectively nominal power and effective number of electrical receivers of the line in question or substation.

Table 3-7. Coefficient of maximum $K_м$ for different coefficients of use $K_и$ in depending on an effective number of electrical receivers.

$n_э$	$K_и$ 0.1	0,15	0.2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
4	3,43	3,11	2,64	2,14	1,87	1,65	1,46	1,29	1,14	1,05
5	3,23	2,87	2,42	2	1,76	1,57	1,41	1,26	1,12	1,04
6	3,04	2,64	2,24	1,88	1,66	1,51	1,37	1,23	1,1	1,04
7	2,88	2,48	2,1	1,8	1,58	1,45	1,33	1,21	1,09	1,04
8	2,72	2,31	1,99	1,72	1,52	1,4	1,3	1,2	1,08	1,04
9	2,56	2,2	1,9	1,65	1,47	1,37	1,28	1,18	1,08	1,03
10	2,42	2,1	1,84	1,6	1,43	1,34	1,26	1,16	1,07	1,03
12	2,24	1,96	1,75	1,52	1,36	1,28	1,23	1,15	1,07	1,03
14	2,1	1,85	1,67	1,45	1,32	1,25	1,2	1,13	1,07	1,03
16	1,99	1,77	1,61	1,41	1,28	1,23	1,18	1,12	1,07	1,03
18	1,91	1,7	1,55	1,37	1,26	1,21	1,16	1,11	1,06	1,03
20	1,84	1,65	1,5	1,34	1,24	1,2	1,15	1,11	1,06	1,03
25	1,71	1,55	1,4	1,28	1,21	1,17	1,14	1,1	1,06	1,03
30	1,62	1,45	1,34	1,24	1,19	1,16	1,13	1,1	1,05	1,03
35	1,56	1,41	1,3	1,21	1,17	1,15	1,12	1,09	1,05	1,02
40	1,5	1,37	1,27	1,19	1,15	1,13	1,12	1,09	1,05	1,02
45	1,45	1,33	1,25	1,17	1,14	1,12	1,11	1,08	1,04	1,02
50	1,4	1,3	1,23	1,16	1,14	1,11	1,1	1,08	1,04	1,02
60	1,32	1,25	1,19	1,14	1,12	1,11	1,09	1,07	1,03	1,02
70	1,27	1,22	1,17	1,12	1,1	1,1	1,09	1,06	1,03	1,02
80	1,25	1,2	1,15	1,11	1,1	1,1	1,08	1,06	1,03	1,02
90	1,23	1,18	1,13	1,1	1,09	1,09	1,08	1,05	1,02	1,02
100	1,21	1,17	1,12	1,1	1,08	1,08	1,07	1,05	1,02	1,02
120	1,19	1,16	1,12	1,09	1,07	1,07	1,07	1,05	1,02	1,02
140	1,17	1,15	1,11	1,08	1,06	1,06	1,06	1,05	1,02	1,02
160	1,16	1,13	1,1	1,08	1,05	1,05	1,05	1,04	1,02	1,02
180	1,16	1,12	1,1	1,08	1,05	1,05	1,05	1,04	1,01	1,01
200	1,15	1,12	1,09	1,07	1,05	1,05	1,05	1,04	1,01	1,01
220	1,14	1,12	1,08	1,07	1,05	1,05	1,05	1,04	1,01	1,01
240	1,14	1,11	1,08	1,07	1,05	1,05	1,05	1,03	1,01	1,01
260	1,13	1,11	1,08	1,06	1,05	1,05	1,05	1,03	1,01	1,01
280	1,13	1,1	1,08	1,06	1,05	1,05	1,05	1,03	1,01	1,01
300	1,12	1,1	1,07	1,06	1,04	1,04	1,04	1,03	1,01	1,01

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In this case is not considered the load of stand-by electrical receivers, repair arc welding transformers and other repair electrical receivers, fire pumps, or electrical receivers, which work short-term (drainage pumps of gate, valves/gates, plate locks, etc.). The load of such electrical receivers is considered only during the calculation of feeding these receivers lines and lines, which feed power distribution points, to which they are connected.

The determination of an effective number of electrical receivers, coefficients of maximum and demand for the conditional electrical receivers, calculated according to formula (3-26), is conducted by the method, presented above for the individual receivers.

During the final peg count summary must be taken into consideration the reactive power of those connected of the network/grid of capacitor banks (power of batteries of static capacitors/condensers are considered with the sign "minus"), and also loss of active and reactive power in the step-down transformers.

For the electrical receivers with the slightly varying in the

time load (pumps of water supply, fans, heating and heaters, resistance furnaces, etc.) the coefficient of demand can be assumed equal to the coefficient of the use:

$$K_{с}=K_{и}. \qquad (3\text{-}27)$$

The method of determining design loads presented is recommended to apply at all steps/stages and for all elements of the system of the power supply of industrial enterprises without the introduction to the calculations of the reducing coefficients. Is allowed/assumed the use/application of a coefficient of participation in the maximum in limits of 0.9-0.95 in cases when during the determination of loads at the highest steps/stages of the system of power supply it is possible to expect noncoincidence in the time of the maximally loaded exchanges, and also during the tentative calculations.

Table 3-8 gives total hours of utilization of maximum power for the lighting load of industrial enterprises.

Example to 3-1. In the separation/department of the shop of industrial enterprise is established/installed the group of electric motors to the nominal voltage 380V with the continuous duty. By the value of the coefficient of use the electrical receivers are divided/marked off into three subgroups, for each of which Table 3-9 shows a number and the power of engines, total nominal power, values of the coefficients of use and power.

It is necessary to determine design loads for the entire group of the electric motors of separation/department.

Solution. Are determined values $tg\varphi$ on Tables 1-2 in depending on values $\cos\varphi$ (obtained values are shown in Table 3-9).

For each of the subgroups of engines are determined average/mean power for the most loaded exchange.

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For the first subgroup average/mean active power on (3-12) is equal to:

$$p_{см1}=266\cdot 0,6=160 \text{ квт};^{(1)}$$

Key: (1). kW.

average/mean reactive power on (3-8)

$$q_{см1}=160\cdot 0,62=99 \text{ квар}.^{(1)}$$

Key: (1). kilovar.

Analogously are determined average/mean power for the second and third subgroups of electric motors.

The total average/mean active and reactive power of the separation/department of shop for the most loaded exchange are equal respectively:

$$P_{см}=160+126+34=320 \text{ квт};^{(1)}$$
$$Q_{см}=99+111+45=255 \text{ квар}.^{(2)}$$

Key: (1). kW. (2). kilovar.

Table 3-8. Annual total hours of utilization of a maximum lighting load.

(1) Род осветительной нагрузки	Число часов использования максимальной мощности (2)
(3) *Внутреннее освещение для географических широт 40—60°*	
(4) Рабочее освещение:	
(5) при одной смене	150—400
(6) при двух сменах	1 750—2 000
(7) при трех сменах	3 800—4 300
(8) Аварийное общее освещение	4 800
(9) Дополнительные светильники аварийного освещения	4 100
(10) *Наружное освещение (для всех широт)*	
(11) Рабочее освещение заводских территорий, включаемое ежесуточно:	
(12) на всю ночь	3 600
(13) до 1 ч	2 450
(14) до 24 ч	2 100
(15) То же, включаемое в рабочие дни:	
(12) на всю ночь	3 000
(13) до 1 ч	2 600
(14) до 24 ч	1 750
(16) Охранное освещение, включаемое ежесуточно на всю ночь	3 500
(17) Рабочее освещение территории поселка, включаемое ежесуточно:	
(12) на всю ночь	3 500
(13) до 1 ч	2 350
(14) до 24 ч	1 950

Key: (1). Kind of lighting load. (2). Total hours of utilization of maximum power. (3). Interior lighting for geographical latitudes of 40-60°. (4). Is working illumination. (5). upon one exchange. (6). upon two exchanges. (7). upon three exchanges. (8). Emergency general illumination. (9). Supplementary illuminating lamps of emergency light. (10). Exterior lighting (for all latitudes). (11). Are working illumination of plant territories, including daily (12). on entire night. (13). to 1 h. (14). to 24 h. (15). The same, including during

workdays. (16). Guard illumination, including daily on entire night. (17). Are working illumination of territory of settlement, included daily. (18). Note. Total hours of utilization of working illumination upon one exchange for different geographic latitudes composes. (19). Latitude, deg. (20). Total hours of utilization.

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Average/mean value

$$\operatorname{tg} \varphi = \frac{255}{320} = 0,8.$$

Total number of electric motors

$$n = 2+3+6+4+6+10 = 31.$$

The group coefficient of use for all electric motors is determined on (3-12):

$$K_u = \frac{320}{560} = 0,573.$$

For determining the coefficient of maximum should be found the value of an effective number of electrical receivers. P Power of the greatest engine of group (Table 3-9)

$$p_{y.\text{макс}} = 100 \text{ квт}^{(1)}.$$

Key: (1). kW.

the power of the smallest engine

$$p_{y.\text{мин}} = 4 \text{ квт}^{(1)}.$$

Key: (1). kW.

Electric motors in power on 2.2 kW in this case are not considered, since their total power comprises less than 5o/o total power of the group of the engines:

$$\frac{10\cdot 2.2}{560}\cdot 100=3.93\%<5\%.$$

On (3-16) the value of the relation

$$m=\frac{100}{4}=25.$$

According to data of Table 3-5 effective number of electrical receivers cannot be equated to their real number and must be determined according to Tables 3-6 in depending on values p and n.

As can be seen from Table 3-9, a number of electrical receivers in the group, the installed power of each of which is equal or more than to the half the power or largest/coarsest receiver, $n_1=2$, since the half the power of largest/coarsest electric motor composes 100/2=50 kW and number indicated it is limited to a number of engines in power on 100 kW. The power of these engines is equal to:

$$p_1=2\cdot 100=200\ \text{квт}.$$

Key: (1). kW.

We find values p and n respectively through (3-17) and (3-18):

$$p_*=\frac{200}{560}=0.358;$$

$$n_*=\frac{2}{31}=0.0645.$$

On Tables 3-6 for obtained values ρ and n we determine the relative value of an effective number of electrical receivers:

$$n_{э*}=0,38$$

(according to note to tables 3-6 for the intermediate value of value n_* is accepted nearest smaller value n_{*}).

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An effective number of electrical receivers is determined on (3-20):

$$n_э=0,38\cdot31=11,8.$$

In depending on the value of the group coefficient of use $K_и=0,575$ and effective number of electrical receivers $n_э=11,8$ in Tables 3-7 by method of interpolation we determine the value of the coefficient of the maximum:

$$K_м=1,24.$$

The values of the calculated ones of the active and reactive power of the separation/department of the shop of enterprise are determined on (3-21) and (3-22):

$$P=1,24\cdot320=397 \text{ квт};^{(1)}$$
$$Q=397\cdot0,8=318 \text{ квар}.^{(2)}$$

Key: (1). kW. (2). kilovar.

The amount of complete rated power on (3-23) is equal to $S=\sqrt{397^2+318^2}=508$ kVA, and coefficient of power on (3-25)

$$\cos\varphi=\frac{397}{508}=0,78.$$

Example 3-2. To determine design loads for the line on the nominal voltage 6 kV, powering four shop TP, for which by precomputation were determined the power and an effective number of electrical receivers, and also average/mean active and reactive power for the most loaded exchange (see Table 3-10).

The total power of connected to the network/grid capacitor banks composes 650 kilovars.

Solution. We determine the coefficient of utilization of all connected to the line electrical receivers in (3-12):

$$K_{и}=\frac{1\,120}{2\,370}=0,473.$$

Table 3-9. Calculation data for example 3-1.

(3) № подгрупп электроприемников	(1) Количество и номинальная мощность электроприемников						(6) Суммарная мощность, квт	(7) Коэффициент использования	(8) Коэффициент мощности	tg φ	(2) Средняя мощность за наиболее нагруженную смену	
	(4) количество	(5) мощность, квт	(4) количество	(5) мощность, квт	(4) количество	(5) мощность, квт					(9) активная, квт	(10) реактивная, квар
1	2	100	3	22	—	—	266	0,6	0,85	0,62	160	99
2	6	30	—	—	—	—	180	0,7	0,75	0,88	126	111
3	4	17	6	4	10	2,2	114	0,3	0,6	1,33	34	45
(11) Для всей группы электроприемников							560	0,573	0,78	0,80	320	255

(12) Примечание. В первых семи столбцах указаны заданные величины. Остальные величины определены были при решении примера.

Key: (1). Quantity and nominal power of electrical receivers. (2). Average/mean power for most loaded exchange. (3). subgroups of electrical receivers. (4). quantity. (5). power kW. (6). Total power, kW. (7). Coefficient of use. (8). Power factor. (9). active, kW. (10). reactive/jet, kilovar. (11). For entire group of electrical receivers. (12). Note. In the first seven columns are shown the assigned magnitudes. Remaining values were specific during the solution of an example.

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We determine the power of conditional electrical receivers from (3-26): for TP1

$$P_{\text{у}1} = \frac{460}{26} = 17{,}7 \text{ квт}^{(1)};$$

Key: (1). kW.

for TP2

$$P'_{T2} = \frac{1\,200}{45} = 26{,}7 \overset{(1)}{\textit{квт}} \text{ и т. д.}$$

Key: (1). kW, etc.

The results of calculation are shown in Table 3-10.

We compute the relation of the power of the greatest conditional electrical receiver and smallest on (3-16):

$$m = \frac{26{,}7}{8{,}92} = 3.$$

The obtained values of the coefficient of use and value m satisfy the indicated into Table 3-5 conditions, consequently effective number of electrical receivers for the line, which feeds TP1-4, it can be accepted by the equal to a total actual number of conditional receivers $n_э = 139.$

The value of the coefficient of maximum we determine on Tables 3-7 depending on values $K_и = 0{,}473$ and $n_э = 139$:

$$K_м = 1{,}06.$$

The values of design loads (power) we determine from formulas (3-21)-(3-25).

1. With off capacitor banks.

Active power

$$P=1,06\cdot 1\,120=1\,190 \text{ квт}.^{(1)}$$

Key: (1). kW.

$$Q=1\,190\frac{990}{1\,120}=1\,050 \text{ квар}.^{(1)}$$

The reactive power

Key: (1). kilovar.

The total power

$$S=\sqrt{1\,190^2+1\,050^2}=1\,590 \text{ ква}.^{(1)}$$

Key: (1). kVA.

Current of the line

$$I=\frac{1\,590}{\sqrt{3}\cdot 6}=153 \text{ а}.$$

Factor of the power

$$\cos\varphi=\frac{1\,190}{1\,590}=0,75.$$

2. With completely connected capacitor banks.

Active power (disregarding power losses in the capacitors/condensers)

$$P=1\,190 \text{ квт}.^{(1)}$$

Key: (1). kW.

The reactive power

$$Q=1\,050-650=400 \text{ квар.}^{(1)}$$

Key: (1). kilovar.

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The total power

$$S=\sqrt{1\,190^2+400^2}=1\,250 \text{ ква.}^{(1)}$$

Key: (1). kVA.

Current of the line

$$I=\frac{1\,250}{\sqrt{3}\cdot 6}=120\ A$$

Factor of the power

$$\cos\varphi=\frac{1\,190}{1\,250}=0{,}95.$$

3.2. Design loads of habitable and public buildings.

Design loads of habitable and public buildings are determined according to "indications in accordance with the design of urban electrical networks", h. 1, "intrablock electrical networks by voltage of up to 1000V in cities and urban type settlements" (SN 167-61).

During the design of the group network/grid of apartments the minimum norms of specific design loads should be accepted:

12 W/m^2 - for illuminating of living rooms and kitchens:

8 W/m^2 - for illuminating the remaining locations of the general/common/total use of the apartments (but not less than one tube with a power of 25 W for each location);

30-40 W/m^2 - for the appliance load of living rooms and kitchens.

For determining rated power of the separate components/links of the feeding intra-house lighting system of habitable buildings should be used the data of Table 3-11.

Design loads of habitable houses for three basic versions of electric requirements, determined by the degree of the electrification of apartments, are given in Table 3-12.

The values indicated consider the lighting and appliance loads of apartments, and also the lighting load of the public-housing locations of habitable buildings with corresponding coefficients of demand and is not considered the power and illumination loads of the self-contained in the administrative relation uninhabited locations.

Table 3-10. Calculation data for example 3-2.

№ ТП	(2) Номинальная мощность $P_у$, квт	(1) Средняя мощность за наиболее нагруженную смену		(3) Эффективное число электроприемников $n_э$	(4) Мощность условного электроприемника $P'_у$, квт
		(5) активная $P_{см}$, квт	(6) реактивная $Q_{см}$, квар		
1	460	280	240	26	17,7
2	1 200	450	340	45	26,7
3	410	145	170	46	8,92
4	300	245	240	22	13,6
(7) Всего	2 370	1 120	990	139	—

Key: (1). Average/mean power for the most loaded exchange. (2). Nominal power kW. (3). Effective number of electrical receivers. (4). Power of conditional electrical receiver kW. (5). active kW. (6). reactive/jet of kilovar. (7). In all.

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For the cities with the population to 20 thousand inhabitants, with exception of plant settlements, and also for the farmstead buildings-up specific loads are received by the same as for the cities with the population to 1000 thousand inhabitants, but with the coefficient of demand 0.5-0.8.

During the design of intrablock networks/grids one should for the base accept design load of one apartment (on Tables 3-12) and number of apartments, supplied by line or transformer, with

consideration the appropriate coefficient of demand (diversity factor), determined on Tables 3-13.

During the design of the group lighting system of public buildings, hotels, hostels and boarding schools, public-housing locations of habitable buildings (staircase, garrets and basements, boiler, "Red Corners," etc.), and also all remaining placed in the habitable buildings uninhabited locations (commercial and storage location, workshops, studio, barbershop, administrative locations, etc.) calculated load one should determine according to the illumination engineering calculation, accepting the coefficient of demand equal to 1.

Rated power of the network/grid of the feed of plug sockets must be determined taking into account the power of the connected electrical receivers.

Design loads during the introductions/inputs into the public and public-service buildings are determined according to the projects of their internal electrical equipment and electric lighting. The exemplary/approximate values of the values of these loads for the most characteristic buildings are shown in Table 3-14.

For determining design loads of the public and public-service

buildings, in reference to the busbars of transformer point, must be considered the coefficient of the demand (coefficient of participation in the maximum) whose exemplary/approximate values are given in Table 3-15.

Table 3-11. Specific design loads from the illumination and the domestic electric appliances for calculating the soaring network/grid of habitable buildings.

(2) Участок питающей сети	(1) Удельная расчетная нагрузка, отнесенная к жилой (оплачиваемой) площади квартир, для городов с числом жителей, тыс.			
	(3) до 1 000		(4) более 1 000	
	(5) с газификацией	(6) без газификации	(5) с газификацией	(6) без газификации
(7) Лестничные питающие линии (стояки)	18	20	20	25
(8) Внутридомовые питающие линии	15	17	18	22

Key: (1). Specific design load, in reference to the habitable (paid) area of apartments, for the cities with a number of inhabitants, thousand. (2). Section of power line. (3). to. (4). it is more. (5). with gasification. (6). without gasification. (7). Stairs feeding lines (risers). (8). Intra-house feeding lines.

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In the absence of precise data about the building-up of the blocks of city in the projects, which foresee the step by step development of intrablock networks/grids, one should take the averaged values of specific loads on 1 m^2 of the working (useful) area of public buildings according to Table 3-16.

Table 3-12. Specific design loads from the illuminaticn and the domestic electric appliarces for the habitatle houses with the apartments with dwelling space cn the crder cf 30 m².

(2) Типы квартир	(1) Современный проектный уровень (1969—1970 г.)			(5) Перспективный уровень (1975—1980 гг.). Расчетная нагрузка на вводе в дом (при числе квартир, равном 30), вт/м²
	(3) Расчетная нагрузка на вводе в квартиру		(4) Расчетная нагрузка на вводе в дом (при числе квартир, равном 30), вт/м²	
	(6) квт	(7) вт/м²		
(8) 1. Жилые квартиры с газификацией (на весь перспективный период):				
А. Города и поселки с числом жителей до 1 млн.	0,8	27	12	25—30
Б. Города с числом жителей более 1 млн. . .	1	33	15	
(9) 2. Жилые квартиры без газификации — с огневыми плитами на первом этапе и перспективой перехода на стационарные электроплиты:				
А. Города и поселки с числом жителей до 1 млн.	1	33	15	50—55
Б. Города с числом жителей более 1 млн.	1,2	40	18	
(10) 3. Жилые квартиры с установкой кухонных электроплит на первом этапе . . .	4—4,5	133—150	44—50	50—55

(11) Примечания: 1. При жилой оплачиваемой площади квартиры в пределах 25—35 м² расчетные нагрузки квартир принимаются по табл. 3-12 без изменений. Для квартир с жилой площадью больше 35 м² или меньше 25 м² расчетные нагрузки пересчитываются по фактической величине площади, но изменения расчетных нагрузок принимаются не больше чем на ±20% по сравнению с нагрузками, указанными в табл. 3-12 для квартир с жилой площадью, равной 30 м².

2. Расчетные нагрузки для квартир, оборудованных кухонными электроплитами, подлежат уточнению после экспериментальной проверки. Меньшие величины указанных в табл. 3-12 расчетных нагрузок рекомендуется принимать при наличии централизованного горячего водоснабжения.

3. При соответствующих обоснованиях, например при наличии в проектах домов устройств для кондиционирования воздуха, расчетные нагрузки могут приниматься в повышенном по сравнению с данными табл. 3-12 размере.

Key: (1). Contemporary designed level (1969-1970). (2). Types of apartments. (3). Design load during intrcductien/input into apartment. (4). Design lcad during intrcducticn/input into house (with number of apartments, equal to 30) W/m². (5). Promising level

(1975-1980). Design load during the introduction/input into the house (with the number of apartments, equal to 30), W/m². (6). KVM. (7). W/m². (8). 1. Habitable apartments with gasification (for entire promising period): A of city and settlements with number of inhabitants to 1 million. B. Cities with number of inhabitants are more than 1 million. (9). 2. Habitable apartments without gasification - with fire plates/slabs during the first stage and prospect for transition/junction to stationary electric stoves: A. Cities and settlements with a number of inhabitants to 1 million. B. Cities with number of inhabitants are more than 1 million. (10). 3. Habitable apartments with installation of kitchen electric stoves during the first stage. (11). Notes: 1. With the habitable paid the areas apartment within the limits of 25-35 m² design loads of apartments are accepted on Table 3-12 without the changes. For the apartments with the dwelling space more than 35 m² or less than 25 m² design loads are recounted in the actual value of area, but changes in design loads are accepted no more than to +-20o/o in comparison with the loads, indicated in Table 3-12 for the apartments with the dwelling space, the equal to 30 m².

2. Design loads for apartments, equipped by kitchen electric stoves, are subject to refinement after experimental check. The smaller values of indicated in Table 3-12 design loads should be taken in the presence of the centralized hot water supply.

3. With corresponding substantiation, for example with presence in designs of houses of devices/equipment for air conditioning, calculated loads can be accepted in increased in comparison with data of Table 3-12 size/dimension.

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In the precomputations with the rough estimate of the necessary transformer power design load can be determined with the aid of the given total specific load of all users of habitable and public-public-service sectors, in reference to 1 m^2 of the habitable paid area. For the contemporary designed level without the use/application in the habitable houses of kitchen electric stoves the value of specific load it should be taken as equal from 20 W/m^2 (for the low building-up) to 30 W/m^2 (for the multistage building-up).

Table 3-13. Values of the coefficient of demand for different quantity of apartments, which obtain feed from the line or the transformer point.

(2) Наименования потребителей	(1) Число квартир									
	5	10	20	30	40	60	100	200	400	600
(3) Жилые дома без электроплит	0,7	0,62	0,5	0,45	0,43	0,42	0,41	0,39	0,37	0,36
(4) Жилые дома с кухонными электроплитами	0,62	0,47	0,4	0,35	0,33	0,3	0,28	0,26	0,24	0,23

(5) Примечание. При наличии обоснованных данных, учитывающих местные особенности, значения коэффициентов спроса могут приниматься в увеличенном против табл. 3-13 размере, но при условии, чтобы расчетные нагрузки не превышали установленных в гл. VII-1 ПУЭ.

Key: (1). Number of apartments. (2). Designation of users. (3). Habitable houses without electric stoves. (4). Habitable houses with kitchen electric stoves. (5). Note. In the presence of substantiated data that consider local special features/peculiarities, values of the coefficients of demand they can be accepted in the increased against Table 3-13 size/dimension, on under the condition so that design loads would not exceed those established/installed in Chapter VII-1 of the PUE.

Table 3-14. Tentative design loads during the introductions/inputs into the public ones to public-service buildings (illumination, electric appliances, electric motors, etc.).

Table 3-14.

(1) Наименование потребителя	(2) Расчетные нагрузки, квт
(3) Общежития на 200—400 чел.	50—100
(4) Поликлиники на 750 посещений в день	110—150
(5) Больницы на 200—400 коек	255—450
(6) Больницы на 50 коек	50—75
(7) Детские сады на 150 мест (без электроплит)	20—30
(8) Детские ясли на 100 мест (без электроплит)	25—35
(9) Детские сады, совмещенные с яслями, на 135 мест (с электроплитами)	70—75
(10) Школы на число мест порядка 1 000	100—160
(11) Школы на 200—500 мест	50—90
(12) Торговые помещения на 15 рабочих мест	20—30
(13) То же с электрохолодильными установками	50—60
(14) Универмаги на 50 рабочих мест	115—120
(15) Помещения общественного питания на число мест порядка 500 (столовые, рестораны)	150—210
(16) Столовые на 100—200 мест	50—100
(17) Кинотеатры на 800—1 000 мест	150—180
(18) Кинотеатры на 300—500 мест	130—150
(19) Мастерские и комбинаты бытового обслуживания	35—50
(20) Прачечные на 1 400 кг белья в смену	80—105
(21) Баня на 50—100 мест	10—20
(22) Подъемные силовые установки в зданиях (лифты) на секцию	7—10

Key: (1). Designation of user. (2). Design loads, kW. (3). Hostels on 200-400 man. (4). Polyclinics to 750 visits during day. (5). Hospitals to 200-400 cots. (6). Hospitals to 50 cots. (7). Kindergartens in 150 places (without electric stoves). (8). Children's creche in 100 places (without electric stoves). (9). kindergartens, combined with creche, in 135 places (with electric stoves). (10). Schools to number of places of order. (11). Schools in 200-500 places. (12). Commercial locations in 15 work sites. (13). Same with electric cooling installations. (14). Department stores in 50 work sites. (15). Placements of public nutrition to number on the order of 500 (dining rooms, restaurants). (16). Dining rooms in 100-200 places. (17). Cinemas in 800-1000 places. (18). Cinemas in 300-500 places. (19). Workshops and combines of domestic service. (20). Laundries on 1400 kg of linen in exchange. (21). bath in 50-100 places. (22). Lift power plants in buildings (elevators in section).

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Table 3-15. Coefficient of participation in the maximum on the transformer point for the loads of public and public-service buildings.

(1) Наименование потребителя	Коэффициент участия в максимуме (2)
(3) Школы, детские учреждения, лечебные учреждения, предприятия общественного питания и бытового обслуживания	0,6—0,7
(4) Магазины и зрелищные предприятия	1,0
(5) Административные здания	0,8—0,9
(6) Лифты	0,5—0,8
(7) Прочие силовые приемники	(8) Соответственно характеру их работы

Key: (1). Designation of user. (2). Coefficient of participation in maximum. (3). Schools, children's institutions, therapeutic institutions, enterprises of public nutrition and domestic service. (4). Stores and entertainment enterprises. (5). Administrative buildings. (6). Elevators. (7). Other power points. (8). According to character of their work.

Table 3-16. Averaged specific loads during the introductions/inputs of public and public-service buildings for the step by step design of inner-apartment electrical networks (including power and other loads).

Table 3-16.

(2) Наименование потребителя	(1) Проектный уровень нагрузок, вт/м²	
	(3) современный 1-й этап (1968—1970 гг.)	(4) перспективный этап (1975—1980 гг.)
(5) Общежития	35	75
(6) Больницы и поликлиники	35	75
(7) Детские учреждения:		
1) без применения электроплит на первом этапе	30	90
2) с применением электроплит на первом этапе	80	90
(8) Школы	35	75
(9) Торговые помещения	30	75
(10) Торговые помещения с холодильниками	40	100
(11) Столовые и рестораны (с применением электроплит)	130	250
(12) Кинотеатры	70	200

(13) Примечания: 1. На перспективном этапе предполагается применение электроэнергии для приготовления пищи во всех зданиях, связанных с общественным питанием (столовые, детские учреждения и др.), а также применение устройств кондиционирования воздуха в зданиях столовых, кинотеатров и др.

2. При наличии централизованного горячего водоснабжения к удельным нагрузкам детских учреждений, столовых и ресторанов с применением электрических плит следует применять понижающий коэффициент 0,8.

Key: (1). Designed level of loads, W/m². (2). Designation of user. (3). contemporary 1st stage (1968-1970). (4). promising stage (1975-1980). (5). Hostels. (6). Hospitals and polyclinic. (7). Children's institutions: 1) without use of electric stoves during the first stage. 2) with the use/application of electric stoves during the first stage. (8). Schools. (9). Commercial locations. (10). Commercial locations with coolers. (11). Dining rooms and restaurants (with use/application of electric stoves). (12). Cinemas. (13). Notes: 1. In the promising stage is assumed use of electric power for the preparation of food in all buildings, connected with the public nutrition (table, children's institutions, etc.), and also use/application of devices/equipment of air conditioning in the buildings of dining rooms, cinemas, etc.

2. In presence of centralized hot water supply to specific loads of children's institutions, dining rooms and restaurants with use/application of boiling tables should be applied reducing coefficient of 0.9.

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The coefficient of demand during the determination of design loads of the lines of network/grid 6-10 kV takes as the equal to:

the line of distribution network - 0.9;

the line of power line - 0.81.

Example 3-3. It will determine the calculated resistive load of transformer point in the city with a number of inhabitants to 1 mln. mans/person from whom is obtained the feed:

1) four 50-apartment houses with the gasification of apartments with the dwelling space of each of apartments 32 m²;

2) school in 500 places;

3) dining room in 200 places;

4) food store with electric refrigeration installations in 15 work sites.

Solution. For one apartment with dwelling spaces 32 m^2 with gasification in the city with a number of inhabitants to 1 mln. mans/person on Tables 3-12 rated power is equal to 0.8 kW. The total number of apartments in four houses comprises 4•50=200 apartments.

Rated power 200 apartments without taking into account the coefficient of demand is equal to:

$$0{,}8\cdot 200=160 \text{ квт.}^{(1)}$$

Key: (1). kW.

The coefficient of demand for 200 apartments without the electric stoves with the gasification is determined on Table 3-13:

$$K_c=0{,}39.$$

Design load for four habitable houses with consideration the coefficient of demand comprises:

$$P_1=0{,}39\cdot 160=62{,}5 \text{ квт.}^{(1)}$$

Key: (1). kW.

Design loads of public buildings on entrance it is determined on Table 3-14:

school in 500 places - 90 kW;

dining room in 200 places - 100 kW;

food store - 55 kW.

The coefficients of participation in the maximum of the users indicated for the transformer point according to Table 3-15 are equal: school and dining room - 0.65; store - 1.0.

Design load of public buildings with consideration the coefficients of demand and participation in the maximum

$$P_2 = 0{,}65 \cdot 90 + 0{,}65 \cdot 100 + 1 \cdot 55 = 178{,}5 \text{ квт.}^{(1)}$$

Key: (1). kW.

The total calculated resistive load of transformer point comprises:

$$P = 62{,}5 + 178{,}5 = 241 \text{ квт.}^{(1)}$$

Key: (1). kW.

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Section Four.

SELECTION OF THE SECTIONS OF WIRES AND CABLES ACCORDING TO THE CONDITION OF HEATING.

4.1. Permissible current loads on wires, cables and busbars.

The permissible current load on the wire, the cable or the busbar is determined from the relationship/ratio

$$I_{д}=K_{п}I_{д.д.} \qquad (4\text{-}1)$$

where $I_{д.д}$ - permissible prolonged current load on the wire, the cable or the busbar under standard conditions of the separator (see Table 4-1-4-20 and 4-27-4-31);

$K_{п}$ - the correction factor, which considers changes in the conditions of the wiring and cables and equal to the product of the separate correction factors:

$$K_{п}=K_1K_2K_3\ldots \qquad (4\text{-}2)$$

Correction factors are considered:

K_1 - an actual ambient temperature;

K_2 - number of laid in the trench working cables;

K_3 - condition of the short-term or intermittent duty of the electrical receivers;

K_4 - section of cable and its location with the separator in the block;

K_5 - voltage of cable with the separator in the block;

K_6 - total daily mean load of cables with the separator in the block;

K_7 - cable laying in two parallel blocks of the identical layout;

K_8 - wiring in the ducts and the chutes/trays;

K_9 - increase in the permissible load on the cables to 10 kV during the emergency mode;

K_{10} - location of busbars on the insulators.

The permissible prolonged current loads on the wires and the

cables are given in the tables for the conditions of heating with the half-hour maximum current load, which is the greatest of the average half-hour current loads of this element/cell of network/grid.

PP Correction for ambient temperature. By normal ambient temperature with the wiring and cables in air it is considered +25°C, also, with the cable laying in the earth/ground or water of +15°C. At actual temperature of the air or earth/ground, different from values indicated above, is introduced correction factor K_1, determined from Table 4-32 in depending on the specified temperature of wires, busbars or strands of cable, indicated in Table 4-33. This coefficient is recommended to apply only in the cases of considerable deviation of temperature from the normal (areas of the extreme north, of the permafrost, tropics, etc.).

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For the bare wires of air electric power lines by voltage higher 1000V correction factor by the temperature of air is not applied.

Correction for a quantity of cables, laid in the general/common/total trench. With the separator in the general/common/total trench of more than one cable is introduced correction factor K_2, determined on Tables 4-21. Unloaded reserve

cables in this case are not considered.

If the part of the cables, laid in the general/common/total trench, is loaded completely, and another part - only to 50o/c, then during the determination of the load, permitted for the completely loaded cables, are accepted coefficients according to Tables 4-35.

Correction for the intermittent and short-term operating modes. During the intermittent or short-term mode/conditions of the work of electrical receivers is introduced the correction factor, equal to:

$$K_3 = \frac{0.875}{\sqrt{\Pi B}}, \qquad (4\text{-}3)$$

where PV - the relative duration of operating cycle, equal to the ratio of time t_p of the start of electrical receiver to the total time of the duration of the cycle of intermittent service $t_ц$:

$$\Pi B = \frac{t_p}{t_ц}. \qquad (4\text{-}4)$$

Coefficient K_3, which considers the intermittent duty of electrical receivers, is introduced for the copper conductors by section not less than 10 mm² and aluminum ones by section not less than 16 mm² when the duration of operating cycle does not exceed 4 min, and the duration of the subsequent pause is not less than 6 min.

Correction for the cables, laid in the blocks. The permissible prolonged current loads for run in the blocks copper triple-cores cable section 95 mm² on the voltage 10 kV into the dependence on the

layout of block and location of cable in the block are given in Table 4-22. For other conditions of the separator of copper cables in the block are introduced the correction factors: in the section of cable - K_4 in Table 4-23, to the voltage - K_5 on Table 4-24, for the daily mean load of the cables, laid in the block, K_6 on Table 4-25 and to the condition of separator in two blocks of identical layout - K_7 on Table 4-26.

Correction for the separator of conductors in boxes and chutes/trays. With the separator of conductors in the ducts, and also the chutes/trays as beams the permissible prolonged current loads are received with a number of wires to 4 on Tables 4-1 and 4-2 as for the conductors, laid in the tubes.

With a number of simultaneously loaded conductors it is more than 4, laid in the tubes, the ducts, and also the chutes/trays by beams, loads on conductors must be accepted on Tables 4-1 and 4-2 for the surface work (in the air) with the introduction of correction factor of K_8, equal for five-six conductors 0.68 for seven - nine conductors 0.63 and for 10-12 conductors 0.6.

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Current loads on the wires, laid in the chutes/trays with the

single-row separator (not in the beams), one should accept as for the wires, laid in the air.

Correction for the cables with the paper insulation, which work under the emergency conditions. For the paper-insulated cables by voltage to 10 kV inclusively, that work in the normal continuous duty with the load, which does not exceed 80o/o of permissible prolonged current in the heating, on the period of the liquidation of the emergency (not more than 5 days) is allowed/assumed into the hours of maximum (by duration of more than 6 h) overloading to 130o/o, which is considered by the introduction of coefficient of K_9=1.3.

Correction for the busbars during their attachment for the insulators prone. The permissible current loads for the busbars of rectangular cross section with their vertical run on the insulators are given in Table 4-30. With location of busbars on the insulators prone to the permissible load is introduced correction factor K_{10}, equal for the busbars in bandwidth to 60 mm 0.95 and for the busbars in bandwidth of more than 60 mm 0.92.

During the determination of the permissible loads on the wires, run in one tube, zero working or ground wire of the four-wire system of three-phase current taking into account is accepted.

Zero conductors in the four-wire system of three-phase current must have conductivity not less than 50o/o, but in the necessary cases it can be increased to 100c/c of conductivity of phase conductors. Is permitted the use/application of wires and cables with the smaller conductivity until the change of GOST to these wires and cables.

According to the solution Soyuzglavenergo No. E/6-62 of 17 March, 1962, in the four-wire nets of alternating current with the dead ground of neutral is allowed/assumed to apply three-strand power cables in the aluminum shell to the nominal voltage 1 kV with the use of their aluminum shells as the zero working wire, with exception:

1) the dangerously explosive installations;

2) the installations in which during the normal operation the neutral current exceeds 75c/c of current of phase conductors.

In this case the permissible prolonged current loads on triple-cores cable take as the equal to the permissible current loads for the four-wire cables with the same section of phase conductors.

For the cables, laid in air, the permissible long current loads are accepted for the clearances between the cables with the separator

of them inside, also, out of the buildings and in the tunnels not less than 35 mm, also, with the separator in the channels not less than 50 mm with any number of laid cables. Permissible prolonged current load to the single cables, run in the earth/ground in the tubes without mechanical ventilation, must be accepted as for the same cables, run in the air.

With the mixed cable laying the permissible prolonged current loads are accepted for the section of route with the worst thermal conditions, if length of this section are more than 10 m. In the case indicated with the large total length of cable route one should apply the cable insert of larger section in order not to increase the section of cable for entire elongation/extent.

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Table 4-1. Wires and cords with the copper veins/strands with the rubber and polychlorovinyl insulation.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а					
	(4) Провода, проложенные открыто	(3) Провода, проложенные в одной трубе				
		(5) два одножильных	(6) три одножильных	(7) четыре одножильных	(8) один двухжильный	(9) один трехжильный
0,5	11	—	—	—	—	—
0,75	15	—	—	—	—	—
1	17	16	15	14	15	14
1,5	23	19	17	16	18	15
2,5	30	27	25	25	25	21
4	41	38	35	30	32	27
6	50	46	42	40	40	34
10	80	70	60	50	55	50
16	100	85	80	75	80	70
25	140	115	100	90	100	85
35	170	135	125	115	125	100
50	215	185	170	150	160	135
70	270	225	210	185	195	175
95	330	275	255	225	245	215
120	385	315	290	260	295	250
150	440	360	330	—	—	—
185	510	—	—	—	—	—
240	605	—	—	—	—	—
300	695	—	—	—	—	—
400	830	—	—	—	—	—

Key: (1). Current loads, A. (2). Section of current-conducting vein/strand, mm². (3). Wires, laid in one tube. (4). Wires, laid opened. (5). two single-cable. (6). three single-cable. (7). four single-cable. (8). one twin-cored. (9). one three-strand.

Table 4-2.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а					
	(4) Провода, проложенные открыто	(3) Провода, проложенные в одной трубе				
		(5) две одножильных	(6) три одножильных	(7) четыре одножильных	(8) один двухжильный	(9) один трехжильный
2,5	24	20	19	19	19	16
4	32	28	28	23	25	21
6	39	36	32	30	31	26
10	55	50	47	39	42	38
16	80	60	60	55	60	55
25	105	85	80	70	75	65
35	130	100	95	85	95	75
50	165	140	130	120	125	105
70	210	175	165	140	150	135
95	255	215	200	175	190	165
120	295	245	220	200	230	190
150	340	275	255	—	—	—
185	390	—	—	—	—	—
240	465	—	—	—	—	—
300	535	—	—	—	—	—
400	645	—	—	—	—	—

Key: (1). Current loads, A. (2). Section of current-conducting vein/strand, mm². (3). Wires, laid in one tube. (4). Wires, laid opened. (5). two single-cable. (6). three single-cable. (7). four single-cable. (8). one twin-cored. (9). one three-strand.

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Table 4-3. Wires with the copper veins/strands with the rubber insulation in the metal shielding shells and cables with the copper veins/strands with rubber insulation in the lead, the polychlorovinyl and incombustible the rubber shells, armored and not armored.

(5) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а, проводов и кабелей[1]				
	(2) одножильных	(3) двухжильных		(4) трехжильных	
	(6) при прокладке				
	(7) в воздухе	(7) в воздухе	(8) в земле	(7) в воздухе	(8) в земле
1,5	23	19	33	19	27
2,5	30	27	44	25	38
4	41	38	55	35	49
6	50	50	70	42	60
10	80	70	105	55	90
16	100	90	135	75	115
25	140	115	175	95	130
35	170	140	210	120	180
50	215	175	265	145	225
70	270	215	320	180	275
95	325	260	385	220	330
120	385	300	445	260	385
150	440	350	505	305	435
185	510	405	570	350	500
240	605	—	—	—	—

Key: (1). Current loads, A, of wires and cables[1].

FOOTNOTE [1]. Current loads relate to the wires and the cables both with the grounding vein/strand and without it. ENDFOOTNOTE.

(2). single-cable. (3). twin-cored. (4). three-strand. (5). Section of current-conducting vein/strand, mm². (6). with separator. (7). in air. (8). in earth/ground.

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Table 4-4. Cables with the aluminum veins/strands with the rubber insulation in the lead, the polychlorovinyl and incombustible the rubber shells, armored and not armored.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а, кабелей				
	(3) одножильных	(4) двухжильных		(5) трехжильных	
	(6) в воздухе	(6) в воздухе	(7) в земле	(6) в воздухе	(7) в земле
2,5	23	21	34	19	29
4	31	29	42	27	38
6	38	38	55	32	46
10	60	55	80	42	70
16	75	70	105	60	90
25	105	90	135	75	115
35	130	105	160	90	140
50	165	135	205	110	175
70	210	165	245	140	210
95	250	200	295	170	255
120	295	230	340	200	295
150	340	270	390	235	335
185	395	310	440	270	385
240	465	—	—	—	—

Key: (1). Current loads, A, of cables. (2). Sections of current-conducting vein/strand, mm². (3). single-cable. (4). twin-cored. (5). three-strand. (6). in air. (7). in ground.

Table 4-5. Cords movable hose lungs and average/mean, cables movable hose heavy, cables mine flexible hose, searchlight and wires are movable.

Table 4-5.

(2). Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а, шнуров, проводов и кабелей[1]		
	(3) одножильных	(4) двухжильных	(5) трехжильных
0,5	—	12	—
0,75	—	16	14
1,0	—	18	16
1,5	—	23	20
2,5	40	33	28
4	50	43	36
6	65	55	45
10	90	75	60
16	120	95	80
25	160	125	105
35	190	150	130
50	235	185	160
70	290	235	200

Key: (1). Current loads, A, of cords, wires and cables[1].

FOOTNOTE [1]. They relate to cords, wires and cables both with the grounding vein/strand and without it. ENDFOOTNOTE.

(2). Section of current-conducting vein/strand, mm². (3). Single-cable. (4). twin-cored. (5). three-strand.

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Table 4-6. Cables movable hose with the rubber insulation for the peat mining enterprises.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а, кабелей напряжением, кв		
	0,5	3	6
6	44	45	47
10	60	60	65
16	80	80	85
25	100	105	105
35	125	125	130
50	155	155	160
70	190	195	—

Key: (1). current loads, A, of cables by voltage, kV. (2). Section of current-conducting vein/strand, mm².

Table 4-7. Cables are hose with the rubber insulation for the movable electrical receivers.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а, на кабели напряжением¹, кв		(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а, на кабели напряжением¹, кв	
	3	6		3	6
16	85	90	70	215	220
25	115	120	95	260	265
35	140	145	120	305	310
50	175	180	150	345	350

Key: (1). Current loads, A, on cables to voltages¹, kV.

FOOTNOTE ¹. Current loads relate to the cables both with the grounding vein/strand and without it. ENDFOOTNOTE.

(2). Section of current-conducting vein/strand, mm².

Table 4-8. Wires with the copper veins/strands with rubber insulation for the electrified transport to voltages 1, 3 and 4 kV.

(1) Сечение токопроводящих жил, мм²	(2) Токовая нагрузка, а	(1) Сечение токопроводящих жил, мм²	(2) Токовая нагрузка, а	(1) Сечение токопроводящих жил, мм²	(2) Токовая нагрузка, а
1,0	20	16	115	120	390
1,5	25	25	150	150	445
2,5	40	35	185	185	505
4	50	50	230	240	590
6	65	70	285	300	670
10	90	95	340	350	745

Key: (1). The section of those conducting current strands, mm². (2). Current load, A.

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Table 4-9. Cables with the ccpper veins/strands with the paper insulation, saturated with oil-rosin and which not discharges by masses, in the lead or aluminum shell, run in the earth/grcund.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а					
	(4) Одножильные кабели до 1 кв*	(5) Двухжильные кабели до 1 кв	(3) Трехжильные кабели			(6) Четырехжильные кабели до 1 кв
			(7) до 3 кв	(8) 6 кв	(9) 10 кв	
2,5	—	45	40	—	—	—
4	80	60	55	—	—	50
6	105	80	70	—	—	60
10	140	105	95	80	—	85
16	175	140	120	105	95	115
25	235	185	160	135	120	150
35	285	225	190	160	150	175
50	360	270	235	200	180	215
70	440	325	285	245	215	265
95	520	380	340	295	265	310
120	595	435	390	340	310	350
150	675	500	435	390	355	395
185	755	—	490	440	400	450
240	880	—	570	510	460	—
300	1 000	—	—	—	—	—
400	1 220	—	—	—	—	—
500	1 400	—	—	—	—	—
625	1 520	—	—	—	—	—
800	1 700	—	—	—	—	—

Key: (1). Current loads, A. (2). Section of current-conducting vein/strand, mm². (3). Iriple-ccres cable. (4). Single-core cables to 1 kV[1].

FOOTNOTE [1]. For the work with direct current. ENDFOOTNOTE.

(5). Two-core cables to 1 kV. (6). Four-wire cables to 1 kV. (7). to 3 kV. (8). kV.

Table 4-10. Cables with the copper veins/strands with the paper insulation, saturated with oil-rosin and which not discharges by masses, in the lead covering, run in the water.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а			
	(3) Трехжильные кабели			(4) Четырехжильные кабели до 1 кв
	(5) до 3 кв	(6) 6 кв	(6) 10 кв	
16	—	135	120	—
25	210	170	150	195
35	250	205	180	230
50	305	255	220	285
70	375	310	275	350
95	440	375	340	410
120	505	430	395	470
150	565	500	450	—
185	615	545	510	—
240	715	625	585	—

Key: (1). Current loads, A. (2). Section of current-conducting vein/strand, mm². (3). Triple-cores cable. (4). Four-wire cables to 1 kV. (5). to 3 kV. (6). kV.

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Table 4-11. Cables with the copper veins/strands with the paper insulation, saturated with oil-rosin and which not discharges by masses, in the lead or aluminum shell, run in the air.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а					
	(4) Одножильные кабели до 1 кв*	(5) Двухжильные кабели до 1 кв	(3) Трехжильные кабели			(6) Четырехжильные кабели до 1 кв
			(7) до 3 кв	(8) 6 кв	(9) 10 кв	
2,5	40	30	28	—	—	—
4	55	40	37	—	—	35
6	75	55	45	—	—	45
10	95	75	60	55	—	60
16	120	95	80	65	60	80
25	160	130	105	90	85	100
35	200	150	125	110	105	120
50	245	185	155	145	135	145
70	305	226	200	175	165	185
95	360	275	245	215	200	215
120	415	320	285	250	240	260
150	470	375	330	290	270	300
185	525	—	375	325	305	340
240	610	—	430	375	350	—
300	720	—	—	—	—	—
400	880	—	—	—	—	—
500	1 020	—	—	—	—	—
625	1 180	—	—	—	—	—
800	1 400	—	—	—	—	—

Key: (1). Current loads, A. (2). Section of current-conducting vein/strand, mm². (3). Triple-cores cable. (4). Single-core cables to 1 kV[1].

FOOTNOTE [1]. for the work with the direct current. ENDFOOTNOTE.

(5). two-core cables to 1 kV. (6). Four-wire cables to 1 kV. (7). to

3 kV. (8). kV.

Table 4-12. Cables with the aluminum veins/strands with paper insulation, saturated with oil-rosin and not discharging masses, in the lead or aluminum shell, run in the earth/ground.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а					
	(4) Одножильные кабели до 1 кв*	(5) Двухжильные кабели до 1 кв	(3) Трехжильные кабели			(6) Четырехжильные кабели до 1 кв
			(7) до 3 кв	(8) 6 кв	(8) 10 кв	
2,5	—	35	31	—	—	—
4	60	46	42	—	—	38
6	80	60	55	—	—	46
10	110	80	75	60	—	65
16	135	110	90	80	75	90
25	180	140	125	105	90	115
35	220	175	145	125	115	135
50	275	210	180	155	140	165
70	340	250	220	190	165	200
95	400	290	260	225	205	240
120	460	335	300	260	240	270
150	520	385	335	300	275	305
185	583	—	380	340	310	345
240	675	—	440	390	355	—
300	770	—	—	—	—	—
400	940	—	—	—	—	—
500	1 080	—	—	—	—	—
625	1 170	—	—	—	—	—
800	1 310	—	—	—	—	—

Key: (1). Current loads, A. (2). Section of current-conducting vein/strand, mm². (3). Triple-cores cable. (4). Single-core cables to 1 kV[1].

FOOTNOTE [1]. for the work with the direct current. ENDFOOTNOTE.

(5). two-core cables to 1 kV. (6). Four-wire cables to 1 kV. (7). to 3 kV. (8). kV.

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Table 4-13. Cables with aluminum veins/strands with the paper insulation, saturated with oil-rosin and which not discharges by masses, in the lead covering, run in the water.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а			
	(3) Трехжильные кабеля			(4) Четырехжильные кабели до 1 кв
	(5) до 3 кв	(6) 6 кв	10 кв	
16	—	105	90	—
25	160	130	115	150
35	190	160	140	175
50	235	195	170	220
70	290	240	210	270
95	340	290	260	315
120	390	330	305	360
150	435	385	345	—
185	475	420	390	—
240	550	480	450	—

Key: (1). Current loads, A. (2). Section of current-conducting vein/strand, mm². (3). Triple-cores cable. (4). Four-wire cables to 1 kV. (5). to 3 kV. (6). kV.

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Table 4-14. Cables with the aluminum veins/strands with the paper insulation, saturated with oil-rosin and non-flowing masses, in lead or aluminum shell, run in the air.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а					
	(4) Одножильные кабели до 1 кв*	(5) Двухжильные кабели до 1 кв	(3) Трехжильные кабели			(6) Четырехжильные кабели до 1 кв
			(7) до 3 кв	(8) 6 кв	(9) 10 кв	
2,5	31	23	22	—	—	—
4	42	31	29	—	—	27
6	55	42	35	—	—	35
10	75	55	46	42	—	45
16	90	75	60	50	46	60
25	125	100	80	70	65	75
35	155	115	95	85	80	95
50	190	140	120	110	105	110
70	235	175	155	135	130	140
95	275	210	190	165	155	165
120	320	245	220	190	185	200
150	360	290	255	225	210	230
185	405	—	290	250	235	260
240	470	—	330	290	270	—
300	555	—	—	—	—	—
400	675	—	—	—	—	—
500	785	—	—	—	—	—
625	910	—	—	—	—	—
800	1 080	—	—	—	—	—

Key: (1). Current loads, A. (2). Section of current-conducting

vein/strand, mm². (3). Triple-cores cable. (4). Single-core cables to 1 kV[1].

FOOTNOTE [1]. For the work with the direct current. ENDFOOTNOTE.

(5). Two-core cables to 1 kV. (6). Four-wire cables to 1 kV. (7). to 3 kV. (8). kV.

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Table 4-15. Cables with the separately lead-lined copper veins/strands are impoverished by the saturated insulation, run in the earth/ground, the air and the water.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а, трехжильных кабелей напряжением, кв					
	6			10		
	(3) в земле	(4) в воздухе	(5) в воде	(3) в земле	(4) в воздухе	(5) в воде
16	90	80	115	—	—	—
25	125	105	155	110	100	140
35	155	125	195	130	120	170
50	185	150	230	160	145	210
70	225	190	280	200	180	255
95	270	230	340	250	220	305
120	310	265	385	290	255	360
150	355	310	450	355	295	405

Key: (1). Current loads, A, of triple-cores cable by voltage, kV. (2). section of current-conducting vein/strand, mm². (3). in earth/ground. (4). in air. (5). in water.

Table 4-16. Cables with the separately lead-lined aluminum veins/strands with specially saturated insulation, run in the earth/ground, the air and the water.

Table 4-16.

(2) Сечение токопроводящей жилы, мм²	(1) Токовые нагрузки, а, трехжильных кабелей напряжением, кв					
	6			10		
	(3) в земле	(4) в воздухе	(5) в воде	(3) в земле	(4) в воздухе	(5) в воде
16	70	60	90	—	—	—
25	95	80	120	85	75	110
35	120	95	150	100	90	130
50	140	115	175	125	110	160
70	175	145	215	155	140	195
95	210	175	260	190	170	230
120	240	205	295	225	195	275
150	275	240	345	260	225	310

Key: (1). Current loads, A, of triple-cores cable by voltage, kV. (2). section of current-conducting vein/strand, mm². (3). in earth/ground. (4). in air. (5). in water.

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Table 4-17. Cables with the copper veins/strands are impoverished by the saturated insulation in the general/common/total lead covering, run in the earth/ground, the air and the water (three-strand, 6 kV).

(1) Сечение токопроводящей жилы, мм²	(2) Токовые нагрузки, а			(1) Сечение токопроводящей жилы, мм²	(2) Токовые нагрузки, а		
	(3) в земле	(4) в воздухе	(5) в воде		(3) в земле	(4) в воздухе	(5) в воде
16	90	65	100	70	220	170	275
25	120	90	140	95	265	210	335
35	145	110	175	120	310	245	385
50	180	140	220	150	355	290	450

Key: (1). Section of the current-conducting vein/strand, mm². (2). Current loads, a. (3). in earth/ground. (4). in air. (5). in water.

Table 4-18. Cables with the aluminum veins/strands are impoverished by the saturated insulation in the general/common/total lead covering, run in the earth/ground, the air and the water (three-strand, 6 kV).

(1) Сечение токопроводящей жилы, мм²	(3) Токовые нагрузки, а			(1) Сечение токопроводящей жилы, мм²	(2) Токовые нагрузки, а		
	(3) в земле	(4) в воздухе	(5) в воде		(3) в земле	(4) в воздухе	(5) в воде
16	70	50	75	70	170	130	210
25	90	70	110	95	205	160	260
35	110	85	135	120	240	190	295
50	140	110	170	150	275	225	345

Key: (1). Section of the current-conducting vein/strand, mm². (2). Current loads, a. (3). in earth/ground. (4). in air. (5). in water.

Table 4-19. Cables with the copper vein/strand with the paper saturated insulation in the lead covering unarmored, run in the air (single-cable).

(1) Сечение токопроводящей жилы, мм²	(2) Токовые нагрузки, а*, кабелей напряжением, кв			(1) Сечение токопроводящей жилы, мм²	(2) Токовые нагрузки, а*, кабелей напряжением, кв		
	(3) до 3	6	10		(3) до 3	6	10
2.5	35	—	—	120	330	300	285
4	50	—	—	150	360	325	310
6	60	—	—	185	385	350	335
10	85	75	—	240	435	395	380
16	120	110	90	300	460	420	405
25	145	135	125	400	485	440	425
35	170	155	145	500	505	460	445
50	215	200	190	625	525	—	—
70	260	240	225	800	550	—	—
95	305	280	265				

Key: (1). Section of the current-conducting vein/strand, mm². (2). Current loads, a[1], cables by voltage, kV.

FOOTNOTE [1]. Current loads relate to the work on alternating current; in this case the lead coverings are connected in they are grounded at both ends/leads: a number by series/row of lying/horizontal cables 3; the distance between the cables in the light/world not more than 125 and is not less than 35 mm. ENDFOOTNOTE.

(3). to.

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Table 4-20. Cables with tne aluminum vein/strand with the paper saturated insulation in tne lead covering unarmcred, run in the air (single-cable).

(1) Сечение токопроводящей жилы, мм²	(2) Токовые нагрузки, а*, кабелей напряжением кв			(1) Сечение токопроводящей жилы, мм²	(2) Токовые нагрузки, а*, кабелей напряжением кв		
	(3) до 3	6	10		(3) до 3	6	
2,5	27	—	—	120	255	230	220
4	38	—	—	150	275	250	240
6	46	—	—	185	295	270	260
10	65	60	—	240	335	305	[illegible]
16	90	85	70	300	355	325	310
25	110	105	95	400	375	340	325
35	130	120	110	500	390	355	340
50	165	155	145	625	405	—	—
70	200	185	175	800	425	—	—
95	235	215	205	—	—	—	—

Key: (1). Section of current-conducting vein/strand, mm². (2). current loads, a[1], cables by voltage kV.

FOOTNOTE [1]. current loads relate to the work on variable/alternating the current; in this case the lead coverings are connected and grounded at both ends/leads; a number by series/row of lying/horizontal cables 3; the distance between the cables in the light/world not more than 125 and is not less than 35 mm. ENDFOOTNOTE.

(3). to.

Table 4-21. Correction factor K_2 to a number of working cables, which lie next at the earth/ground in the tubes and without the tubes.

(1) Число кабелей	1	2	3	4	5	6
(2) Для расстояния в свету 100 мм	1,00	0,90	0,85	0,80	0,78	0,75
(3) То же 200 мм	1,00	0,92	0,87	0,84	0,82	0,81
(3) То же 300 мм	1,00	0,93	0,90	0,87	0,86	0,85

Key: (1). Number of cables. (2). for clearance 100 mm. (3). Then 200 mm.

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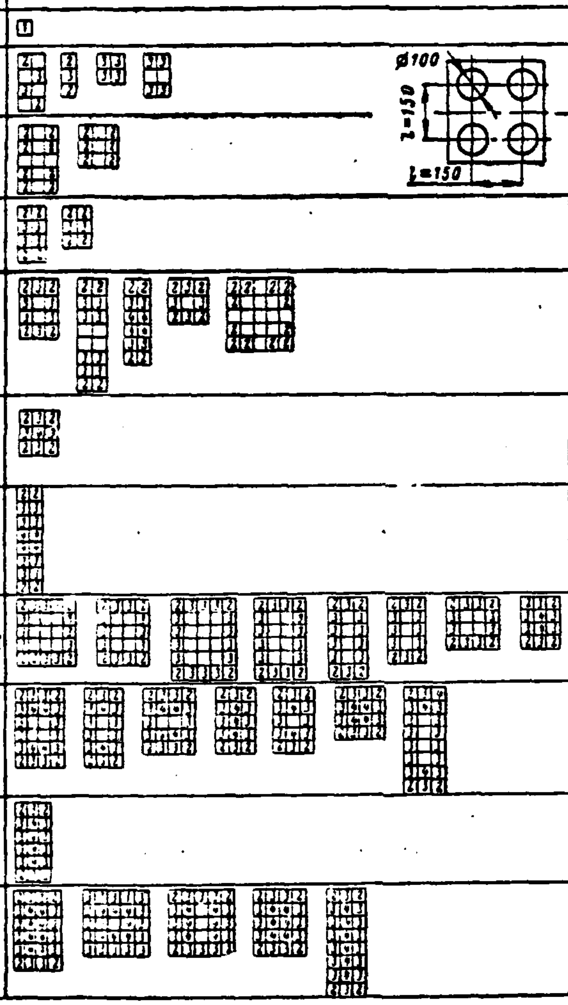
Table 4-22. Filling of blocks with cables.

(1) Группа	(2) Конфигурация блоков	(3) № канала	I_0, a
I		1	191
II		2	173
		3	167
III		2	154
IV		2	147
		3	138
V		2	143
		3	135
		4	131
VI		2	140
		3	132
		4	118
VII		2	136
		3	132
		4	119
VIII		2	135
		3	124
		4	104
IX		2	135
		3	118
		4	100
X		2	133
		3	116
		4	81
XI		2	129
		3	114
		4	79



Note. The current loads I_0 are given for the cables with the copper

veins/strands by section 3x95 mm² on the voltage 10 kV. For other conditions are introduced the correction factors in Tables 4-23, 4-24, 4-25 and 4-26.

Key: (1). Group. (2). Layout of blocks. (3). channel.

Table 4-23. Correction factor K_4 to the section of cable and its location in the block.

(1) Сечение токопроводящей жилы, мм²	(2) Значения коэффициента при номере канала блока			
	1	2	3	4
25	0,44	0,46	0,47	0,51
35	0,54	0,57	0,57	0,60
50	0,67	0,69	0,69	0,71
70	0,81	0,84	0,84	0,85
95	1,00	1,00	1,00	1,00
120	1,14	1,13	1,13	1,12
150	1,33	1,30	1,29	1,26
185	1,50	1,46	1,45	1,38
240	1,78	1,70	1,68	1,55

Key: (1). Section of the current-conducting vein/strand, mm². (2). Values of coefficient with number of channel of block.

Table 4-24. Correction factor K_5 to the voltage of cable.

(1) Номинальное напряжение, кв	10	6	(2) до 3
(3) Значения коэффициента	1	1,05	1,09

Key: (1). Nominal voltage, kV. (2). to. (3). Values of coefficient.

Table 4-25. Correction factor K_6 for the daily mean load of block, determined in depending on the ratio of the daily mean transmitted power to the nominal.

$\frac{S_{ср.с}}{S_н}$	1,0	0,85	0,7
(1) Значения коэффициента	1,0	1,07	1,16

Key: (1). Values of coefficient.

Table 4-26. Coefficient K_7 of decrease in the permissible current load on the cables, run in the parallel blocks of identical layout.

(1) Расстояние между блоками, мм	500	1 000	1 500	2 000	2 500	3 000
(2) Значения коэффициента . .	0,85	0,89	0,91	0,93	0,95	0,96

Key: (1). Distance between blocks, mm. (2). Values of coefficient.

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Table 4-27. Uninsulated copper, aluminum and steel-aluminum wires (GOST 839-59).

(1) Медные			(2) Алюминиевые			(3) Сталеалюминиевые		
(4) Марка провода	(5) Токовая нагрузка, а		(4) Марка провода	(5) Токовая нагрузка, а		(4) Марка провода	(5) Токовая нагрузка, а	
	(6) вне помещений	(7) внутри помещений		(6) вне помещений	(7) внутри помещений		(6) вне помещений	(7) внутри помещений
М-4	50	25	А-16	105	75	АС-10	80	50
М-6	70	35	А-25	135	105	АС-16	105	75
М-10	95	60	А-35	170	130	АС-25	130	100
М-16	130	100	А-50	215	165	АС-35	175	135
М-25	180	135	А-70	265	210	АС-50	210	165
М-35	220	170	А-95	320	255	АС-70	265	210
М-50	270	215	А-120	375	300	АС-95	330	260
М-70	340	270	А-150	440	355	АС-120	380	305
М-95	415	335	А-185	500	410	АС-150	445	365
М-120	485	395	А-240	590	490	АС-185	510	425
М-150	570	465	А-300	680	570	АС-240	610	505
М-185	640	530	А-400	815	690	АС-300	690	585
М-240	760	685	А-500	980	820	АС-400	835	715
М-300	880	740	А-600	1 070	930	—	—	—
М-400	1 050	895				—	—	—

Key: (1). Copper. (2). Aluminum. (3). Steel-aluminum. (4). Brand of wire. (5). Current load, a. (6). outdoors. (7). indoors.

Table 4-28. Uninsulated bronze and steel-bronze wires.

(1) Материал провода	(2) Марка провода	(3) Токовая нагрузка, а*
(4) Бронзовые	Б-50	215
	Б-70	265
	Б-95	330
	Б-120	380
	Б-150	430
	Б-185	500
	Б-240	600
	Б-300	700
(5) Сталебронзовые	БС-185	515
	БС-240	640
	БС-300	750
	БС-400	890
	БС-500	980

Key: (1). Material of wire. (2). Brand of wire. (3). Current load, a[1].

FOOTNOTE [1]. current loads are given for the bronze with specific resistor/resistance $\rho_{20}=0.03$ Ω•mm²/m. ENDFOOTNOTE.

(4). Bronze. (5). Steel-bronze.

Table 4-29. Uninsulated steel wires.

(1) Марка провода	(2) Токовая нагрузка, а	(1) Марка провода	(2) Токовая нагрузка, а
ПСО-3	23	ПС-25	60
ПСО-3,5	26	ПС-35	75
ПСО-4	30	ПС-50	90
ПСО-5	35	ПС-70	125
		ПС-95	135

Key: (1). Brand of wire. (2). Current load, a.

Table 4-30. Busbars of rectangular cross section.

(1) Размеры, мм	(2) Допустимая нагрузка, а				(1) Размеры, мм	(3) Допустимая нагрузка для стальных шин, а	
	(4) Алюминиевые шины		(5) Медные шины				
	(6) переменный ток	(7) постоянный ток	(6) переменный ток	(7) постоянный ток		(6) перемен-ный ток	(7) постоян-ный ток
15×3	165	165	210	210	20×3	65	100
20×3	215	215	275	275	25×3	80	120
25×3	265	265	340	340	30×3	95	140
30×4	365	370	475	475	40×3	125	190
40×4	480	480	625	625	50×3	155	230
40×5	540	545	700	705	60×3	185	280
50×5	665	670	860	870	70×3	215	320
50×6	740	745	955	960	80×3	245	365
60×6	870	880	1 125	1 145	90×3	275	410
80×6	1 150	1 170	1 480	1 510	100×3	305	460
100×6	1 425	1 455	1 810	1 875	20×4	70	115
60×8	1 025	1 040	1 320	1 345	30×4	100	165
80×8	1 320	1 355	1 690	1 775	40×4	130	220
100×8	1 625	1 690	2 080	2 180	50×4	165	270
120×8	1 900	2 040	2 400	2 600	60×4	195	325
60×10	1 155	1 180	1 475	1 525	70×4	225	375
80×10	1 480	1 540	1 900	1 990	80×4	260	430
100×10	1 820	1 910	2 310	2 470	90×4	290	480
120×10	2 070	2 300	2 650	2 950	100×4	325	535

Key: (1). Sizes/dimensicrs, mm. (2). Permissitle load, a. (3). Permissible load for steel tuscars, a. (4). Aluminum busbars. (5). Copper busbars. (6). alternating current. (7). direct current.

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Table 4-31. Conductors with the aluminum busbars of series ShRA and ShMA of the trust Elektromontazhkonstruktsiya.

(1) Тип токопровода	(2) Распределительные			(3) Магистральные		
	ШРА60-2	ШРА60-4	ШРА60-6	ШМА59-1	ШМА59-2	ШМА59-4
(4) Допустимая нагрузка (номинальный ток), *а*	250	400	600	1 500	2 500	4 000

Key: (1). Type of conductor. (2). Distributive. (3). Main-line. (4). Permissible load (rated current), a.

Table 4.32. Correcting coefficient K_1 to the temperatures of the earth/ground and air for the current loads on the cables, uninsulated and insulated wires and busbars.

(1) Расчетная температура среды, °C	(2) Нормированная температура жил, °C	(3) Поправочный коэффициент при фактической температуре среды, °C											
		−5	0	+5	+10	+15	+20	+25	+30	+35	+40	+45	+50
15	80	1,14	1,11	1,08	1,04	1,00	0,96	0,92	0,88	0,83	0,78	0,73	0,68
25	80	1,24	1,20	1,17	1,13	1,09	1,04	1,00	0,95	0,90	0,85	0,80	0,74
25	70	1,29	1,24	1,20	1,15	1,11	1,95	1,00	0,94	0,88	0,81	0,74	0,67
15	65	1,18	1,14	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55
25	65	1,32	1,27	1,22	1,17	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61
15	60	1,20	1,15	1,12	1,06	1,00	0,94	0,88	0,82	0,75	0,67	0,57	0,47
25	60	1,36	1,31	1,25	1,20	1,13	1,07	1,00	0,93	0,85	0,76	0,66	0,54
15	55	1,22	1,17	1,12	1,07	1,00	0,93	0,86	0,79	0,71	0,61	0,50	0,36
25	55	1,41	1,35	1,29	1,23	1,15	1,08	1,00	0,91	0,82	0,71	0,58	0,41
15	50	1,25	1,20	1,14	1,07	1,00	0,93	0,84	0,76	0,66	0,54	0,37	—
25	50	1,48	1,41	1,34	1,28	1,18	1,09	1,00	0,89	0,78	0,63	0,45	—

Key: (1). The calculated temperature of medium. (2). Specified temperature of strands. (3). Correction factor at actual temperature of medium.

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Table 4-33. Permissitle temperatures of heating wires, cables and tusbars.

(1) Наименование	(2) Наибольшая допустимая температура проводов, кабелей и шин при нагревании длительной токовой нагрузкой, °C
(3) Голые провода и шины	+70
(4) Провода и кабели с резиновой или пластмассовой (полихлорвиниловой или полиэтиленовой) изоляцией на напряжение до 6 *кв*	+65
(5) Кабели с пластмассовой изоляцией на напряжение 10 *кв*	+60
(6) Кабели с бумажной изоляцией, пропитанной маслоканифольной или нестекающей массой на напряжение, *кв*:	
(7) до 3	+80
6	+65
10	+60

Key: (1). Designation. (2). Greatest permissitle temperature cf wires, cables and tusbars with heating by prolonged current load. (3). Bare wires and buscars. (4). wires and cables with rubber or plastic (polychlorovinyl or polyethylene) insulation to voltage to 6 kV. (5). cables with molded insulation to voltage 10 kV. (6). Cables with paper insulation, saturated with oil-resin or not discharging mass to voltage, kV. (7). to.

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Table 4-34. Highest mean temperatures of air in 13 h of the day of the hottest month and highest average monthly temperatures of soil for the fundamental areas of the USSR.

(1) Наименование района	(2) Температура, °C		(1) Наименование района	(2) Температура, °C	
	(3) воздуха	(4) почвы на глубине 0,8 м		(3) воздуха	(4) почвы на глубине 0,8 м
(5) Александровск-на-Сахалине	19,1	—	Волгоград (6)	29,0	23,7
(8) Алма-Ата	27,6	—	Вологда (7)	21,1	13,2
(10) Архангельск	18,0	—	Воронеж (9)	25,9	—
(12) Астрахань	29,6	—	Горький (11)	23,1	—
(14) Ашхабад	36,0	—	Грозный (13)	28,8	—
(16) Баку	27,9	—	Дербент (15)	27,3	—
(18) Батуми	25,9	—	Джамбул (17)	30,6	—
(20) Благовещенск	25,7	—	Днепропетровск (19)	26,7	—
(22) Богословск	21,1	—	Ейск (21)	27,9	—
(24) Брянск	22,5	—	Ереван (23)	30,6	—
(26) Витебск	20,3	—	Запорожье (25)	28,5	—
(28) Владивосток	23,2	—	Иваново (27)	22,9	15,0
(30) Владимир	22,4	—	Ирбит (29)	22,5	—
			Иркутск (31)	22,6	12,3

Table 4-34 cont.

(33)Казалинск	32.1	—	Петровский завод (Забайкалье) (34)	22.9	—
(35)Казань	24.0	—	Петрозаводск(36)	19.2	—
(36)Калуга	22.7	—	Полтава (38)	25.0	—
(37)Кемь	16.8	—	Поти (40)	25.9	—
(39)Керчь	26.0	—	Псков (42)	21.0	—
(41)Киев	23.5	17,3	Ростов-на-Дону(44)	28.2	20,2
(43)Киров	21.8	—	Рязань (46)	24.2	—
(45)Кировоград	25.9	—	Самарканд (48)	32.2	—
(47)Кострома	21.3	—	Саратов (50)	27.5	—
(49)Красноводск	32.2	—	Свердловск(52)	21.0	15,8
(51)Краснодар	28.6	—	Севастополь(54)	26.4	—
(53)Красноярск	23.8	—	Семипалатинск (56)	26.9	—
(55)Кривой Рог	28.2	—	Симферополь (58)	26.7	—
(57)Куйбышев	25.2	—	Смоленск (60)	21.6	—
(59)Курган	23.7	—	Соликамск (62)	21.6	—
(61)Курск	23.6	—	Таганрог (64)	27.6	—
(63)Кутаиси	28.0	—	Тамбов(66)	25.1	—
(65)Луганск	27.9	—	Ташкент(68)	33.4	—
(67)Ленинакан	25.8	—	Тбилиси(70)	29.0	—
(69)Ленинград	20.1	16,3	Тобольск(72)	21.5	—
(71)Магнитогорск	22.6	—	Томск(74)	22.5	11,2
(73)Маргелан	33.6	—	Тула(76)	23.1	—
(75)Минск	21.3	—	Туркестан(78)	34.3	—
(77)Москва	21.8	14.4	Тюмень (80)	22.6	—
(79)Мурманск	14.8	—	Ульяновск(82)	23.3	—
(81)Наманган	33.4	—	Уральск (84)	28.6	—
(83)Нарым	21.8	—	Уссурийск(86)	24.5	—
(85)Нерчинск	25.7	—	Уфа (88)	23.3	—
(87)Николаев	28.2	—	Херсон (90)	29.2	21,8
(89)Николаевск-на-Амуре	19.7	—	Ходжент (92)	35.0	—
(91)Новгород	21.5	—	Целиноград(94)	35.2	—
(93)Новороссийск	27.4	—	Чарджуй (96)	35.7	—
(95)Новосибирск	22.8	—	Челябинск (98)	22.6	—
(97)Одесса	26.1	23	Чернигов (100)	23.0	—
(99)Омск	23.3	13.3	Чита (102)	24.1	—
(101)Орджоникидзе	24.0	—	Щегловск (Кузбасс) (104)	23.2	—
(103)Оренбург	26.8	15.6	Якутск(106)	23.0	—
(105)Орел	24.1	17,2	Ярославль (108)	22.3	—
(107)Пенза	24.4	—	Ялта (110)	27.1	—
(109)Пермь	21.8	12,8			

Key: (1). Designation cf area. (2). Temperature. (3). air. (4). soil at depth cf 0.8 m. (5). Aleksandrovsk-na-Sakhalin. (6). Volgcgrad. (7). Vologda. (8). Alma Ata. (9). Voronezh. (10). Arkhangelsk. (11). Gor'kiy. (12). Astrakhar. (13). Grcznyy. (14). Ashkhabad. (15). Derbent. (16). Baku. (17). Dznambul. (18). Batumi. (19). Dneprcpetrovsk. (20). Blagcvesnchenk. (21). Eysk. (22). Bogcslovsk. (23). Yerevan. (24). Bryansk. (25). Zapcrozh'ye. (26).

Vitebsk. (27). Ivanovo. (28). Vladivostok. (29). Irbit. (30). Vladimir. (31). Irkutsk. (32). Kazalinsk. (33). Petrovskiy zavod (Zabaykal'ye). (34). Kazan'. (35). Kaluga. (36). Petrozavodsk. (37). Kem'. (38). Poltava. (39). Kerch'. (40). Poti. (41). Kiev. (42). Pskov. (43). Kirov. (44). Rostov on the Don. (45). Kirovograd. (46). Ryazan'. (47). Kostroma. (48). Samarkand. (49). Krasnovodsk. (50). Saratov. (51). Krasnodar. (52). Sverdlovsk. (53). Krasnoyarsk. (54). Sevastopol. (55). Krivoj Rog. (56). Semipalatinsk. (57). Kuybyshev. (58). Simferopol'. (59). Kurgan. (60). Smolensk. (61). Kursk. (62). Solikamsk. (63). Kustarsi. (64). Taganrog. (65). Lugansk. (66). Tambov. (67). Leninakan. (68). Tashkent. (69). Leningrad. (70). Tbilisi. (71). Magnitogorsk. (72). Tobol'sk. (73). Margelan. (74). Tomsk. (75). Minsk. (76). Tula. (77). Moscow. (78). Turkistan. (79). Murmansk. (80). Tyumen'. (81). Namangan. (82). Ul'yanovsk. (83). Narym. (84). It is Ural. (85). Nerchinsk. (86). Ussuri. (87). Nikolayev. (88). Ufa. (89). Nikolayevsk-na-amur. (90). Kherson. (91). Novgorod. (92). Khodzhent. (93). Novorossisk. (94). Tselinograd. (95). Novosibirsk. (96). Chardzhuy. (97). Odessa. (98). Chelyabinsk. (99). Omsk. (100). Chernigov. (101). Ordzhonikidze. (102). Chita. (103). Orenburg. (104). Shcheglovsk. (Kuzbass). (105). Orel. (106). Yakutsk. (107). Penza. (108). Yaroslavl'. (109). Permian period/Perm'. (110). Yalta.

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Example 4-1. To determine the permissible load on those laid open aluminum wires with the polychlorovinyl insulation by section 35 mm² for the line, which feeds electric motor with the intermittent operating mode.

Duration of the inclusion/connection of electric motor $t_p=2$ min; the general/common/total duration of cycle $t_u=10$ min. Temperature of surrounding air of +25°C.

Solution. Relative duration of operating cycle from (4-4)

$$\Pi B=\frac{2}{10}=0,2.$$

Value of their correction factor (4-3)

$$K_s=\frac{0,875}{\sqrt{0,2}}=1,95.$$

The permissible prolonged current load for the assigned conditions of separator on Table 4-2 is equal to:

$$I_{n.g}=130\ a,$$

whence the permissible load for conditions of intermittent service from (4-1)

$$I_s=1,95\cdot 130=254\ a.$$

Example 4-2. To determine the permissible constant load on the cable 10 kV with the paper insulation with the aluminum veins/strands by section 3x70 mm², laid in the trench at temperature of soil of

+25 °C. In all in the general/common/total trench are laid seven cables with the clearance between the cables 200 mm. One cable stand-by and load does not bear.

Solution. For the assigned conditions from Table 4-12 we find the permissible current load on the cable under standard conditions of the separator:

$$I_{н.д}=165\ a.$$

From Table 4-32 we find correction factor to the temperature of soil at maximum permissible temperature of cable cores 10 kV 60 °C (see Table 4-32):

$$K_t=0{,}88.$$

Table 4-35. Correction factors to a number of working cables, laid by series/row in the earth/ground, taking into account the 50o/c charging of the part of the cables.

(1) Расстояние между кабелями, мм	(2) Число кабелей, загруженных на 100/50%				
	1/5	2/4	3/3	4/2	5/1
100	0,94	0,87	0,82	0,80	0,78
200	0,96	0,92	0,87	0,84	0,82
300	1,00	0,93	0,90	0,87	0,86

Key: (1). Distance between cables, mm. (2). Number of cables, loaded to 100/50o/o.

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Correction for a number of cables (six working cables) we find from Table 4-21:

$$K_2=0{,}81.$$

General/common/total correction factor in (4-2)

$$K_n=0{,}88\cdot 0{,}81=0{,}712.$$

Permissible constant load on the cable on (4.1)

$$I_2=0{,}712\cdot 165=117\ a.$$

Example 4-3. To determine the permissible constant load for the cables with the copper veins/strands, run in channels Nc 4 blocks of group VII under the following conditions: the section of cables 240 mm²; voltage 6 kV; the relative daily mean load of block

$S_{cp.c}/S_{н}=0,85$; at a distance of 2 m from the block in question it is arranged/located the same block.

Solution. On Tables 4-22 for the cable, arranged/located in channel No 4 block of group VII, we find the permissible current load for the cable 3x95 mm² by voltage 10 kV $I_{н.з}=119$ a.

We determine the values of the correction factors:

in the section of cable in Table 4-23 $K_4=1.55$;

to the voltage of cable on Table 4-24 $K_5=1.05$;

for the mean-daily load of block on Table 4.25 $K_6=1.07$;

with the distance between them of 2 m on Table 4-26 $K_7=0.93$.

General/common/total correction factor $K_н=1,55\cdot1,05\cdot1,07\cdot0,93=1.62$.

Permissible load on cable $I_д=1,62\cdot119=193$ a.

4-2. Selection of the maximum current protection of line[1].

FOOTNOTE [1]. See also Section 7. ENDFOOTNOTE.

Safety fuses in electric systems to 1000V.

Distinguish safety fuses with the large thermal inertia, i.e., by the ability to maintain/withstand considerable short-term overloadings by current, and inertia-free, possessing small thermal inertia and, therefore, by the very limited capability for overloadings.

The first include all adjusting safety devices/fuses with the male thread and the lead current-conducting bridge, to the second - tubular safety devices/fuses with the copper current-conducting bridge.

Rated current by smelting insert $I_{в}$ for the safety devices/fuses with the large thermal inertia is determined only by p to the strength of prolonged calculated current of line $I_{дл}$ from the relationship/ratio

$$I_{в} \geq I_{дл}. \qquad (4\text{-}5)$$

Rated current by smelting insert for the inertia-free safety devices/fuses must satisfy two conditions one of which is expressed by relationship/ratio (4-5), and another - one of given is below formulas (4-6), (4-7) or (4-8).

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With the protection or branching to the single electric motor with the infrequent launchings/startings and the duration of start-up time not are more than 2-2.5 s. (electric motors of metal-working machines, fans, pumps, etc.)

$$I_{\text{в}} \geqslant \frac{I_{\text{п}}}{2,5}; \quad (4\text{-}6)$$

with the protection of branching to the single electric motor with the frequent launchings/startings (electric motors of taps/cranes) or the large duration of the start-up time (engines, centrifuges, crushers, etc.)

$$I_{\text{в}} \geqslant \frac{I_{\text{п}}}{1,6 \div 2}; \quad (4\text{-}7)$$

with the protection of main line, which feeds the power or combined loading,

$$I_{\text{в}} \geqslant \frac{I_{\text{кр}}}{2,5}. \quad (4\text{-}8)$$

In the latter/last three formulas: $I_{\text{п}}$ - the starting current of electric motor, a; $I_{\text{кр}}$ - maximum short-term current of the line:

$$I_{\text{кр}} = I'_{\text{п}} + I'_{\text{дл}}, \quad (4\text{-}9)$$

where $I'_{\text{п}}$ - the starting current of electric motor or group of the simultaneously included engines during launching/starting of which the short-term current of line reaches maximum value, a; $I'_{\text{дл}}$ - prolonged calculated current of line to the moment/torque of

launching/starting the electric motor (or the group of engines), determined without taking into account the operating current of started electric motor (or the group of engines), a.

For the electric motors of critical mechanisms for the purpose of the especially reliable turning out of safety devices/fuses from the overshooting it is allowed/assumed when selecting of safety device/fuse to use formula (4-7), accepting denominator equal to 1.6 independent of the conditions of launching/starting the electric motor, if the multiplicity of current short circuit satisfies the conditions, indicated in column 3, Table 7-8.

Rated current by smelting insert for the protection of branching to the welding set is selected from the relationship/ratio

$$I_{в} \geq 1,2\, I_{н.св} \sqrt{ПВ}, \qquad (4\text{-}10)$$

where $I_{н.св}$ - the rated current of welding set with the nominal duration of inclusion/connection, a; PV - nominal duration of the engaging of the apparatus, expressed in the portions of unit.

Rated current by smelting insert for the protection of branching to the welding set can be taken as the equal to the long permissible current upon the run for the feed of welding set wire.

Technical specifications of safety fuses are given in Table

4-36.

The selectivity of protection by the safety fuses of main-line multiended line is achieved by a consecutive increase in the values of the fuse links in the individual sections of line in proportion to approximation/approach to a point/item of feed.

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Table 4-36. Fundamental characteristics of safety devices/fuses to 500V alternating and direct current.

Тип	Номинальный ток патрона, а	Номинальное напряжение, в	Номинальный ток плавкой вставки, а	Техническая характеристика
			1. Трубчатые	
ПР-2	15	220 в в сетях постоянного тока, 380 в в сетях переменного тока I габарита или в сетях 500 в II габарита	6, 10, 15	Закрытые разборные без наполнителя
	60		15, 20, 25, 35, 45, 60	
	100		60, 80, 100	
	200		100, 125, 160, 200	
	350		200, 225, 260, 300, 350	
	600		350, 430, 500, 600	
	1 000		600, 700, 800, 1 000	
НП-5	350	380	200, 225, 300, 350	Патрон с наполнителем
НПН-15	15	500	6, 10, 15	Патрон неразборный с наполнителем
НПН-60	60	500	15, 20, 25, 35, 45, 60	
НПР-100	100	500	60, 80, 100	Патрон с наполнителем
НПР-200	200	500	100, 125, 160, 200	То же
КП-60	60	500	10, 15, 20, 25, 35, 45, 60	» »
КП-200	200	500	60, 80, 100, 125, 160, 200	» »
КП-350	350	500	200, 225, 260, 350	» »
ППТ-10	10	250	4, 6, 10	» »
ПН-Р-100	100	500	30, 40, 50, 60, 80, 100	Закрытые разборные с кварцевым наполнителем
ПН-Р-250	250	500	80, 100, 120, 150, 200, 250	
ПН-Р-400	400	500	200, 250, 300, 350, 400	
ПН2-100/II	100	500	30, 40, 50, 60, 80, 100	Закрытый патрон с наполнителем
ПН2-250/II	250	500	80, 100, 120, 150, 200, 250	
ПН2-400/II	400	500	200, 250, 300, 400	
ПН2-600/II	600	500	300, 400, 500, 600	
			2. Установочные с винтовой резьбой	
ПК-27	20	500	4, 6, 10, 15, 20	
ПД-1, ПДС-1	6	380	1, 2, 4, 6	
ПД-2, ПДС-2	20	380	10, 15, 20	
ПД-3, ПДС-3	60	380	25, 35, 60	
ПД-4, ПДС-4	125	380	80, 100, 125	
ПД-5, ПДС-5	225	380	160, 200, 225	
ПД-6, ПДС-6	350	380	260, 300, 350	
ПД-7	600	380	430, 500, 600	
ПДП-2	20	380	10, 15, 20	
ПДУ-6	6	380	1, 2, 4, 6	
ПДУ-20	20	380	10, 15, 20	
ПРС-6	6	380	1, 2, 4, 6	
ПРС-20	20	380	10, 16, 20	
ПРС-63	63	380	25, 40, 63	
ПРС-100	100	380	80, 100	

Key: (1). Type. (2). Rated current of receptacle, a. (3). Nominal voltage, V. (4). Rated current by smelting insert, a. (5). Technical characteristic. (6). Tubular. (7). 220 V in nets direct currents, 380V in nets of alternating current of I overall size or in nets 500 V of II overall size. (8). Closed dismountable without filler. (9). Receptacle with filler. (10). Receptacle (noncollapsable with filler). (11). the same (12). Closed dismountable with quartz filler. (13). Closed receptacle with filler. (14). Adjusting with male thread.

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Table 4-37. Conditions cf tne selectivity of safety fuses PN2 for the nets of especially critical designation/purpcse.

$I_{к}/I_{в.м}$	10	20	50	100	150 (1) и более
(2) Плавкая вставка с номинальным током $I_{в.м}$ меньшей величины, а	(3) Плавкая вставка с номинальным током $I_{в.б}$ большей величины, а				
30	50	60	120	150	200
40	60	80	120	200	200
50	80	100	120	250	250
60	100	120	150	250	250
80	120	120	200	250	250
100	120	120—150	250	250	250
120	150	200	300	300	300
150	200	250	300	300	300
200	250	300	400	400	400
250	300	400	600	>600	600
300	400	500	>600	—	—
400	600	>600	—	—	—

Key: (1). and more. (2). Fuse link with rated current of smaller value, a. (3). Fuse lirk with rated current cf larger value, a.

Table 4.38. Conditions of the selectivity of safety fuses PN2 for the nets of normal designation/purpose.

$I_в/I_{в.м}$	10	20	50	(1) 100 и более
(2) Плавкая вставка с номинальным током $I_{в.м}$ меньшей величины, а	(3) Плавкая вставка с номинальным током $I_{в.б}$ большей величины, а			
30	40	50	80	120
40	50	60	100	120
50	60	80	120	120
60	80	100	120	120
80	100	120	120	150
100	120	120	150	150
120	150	150	250	250
150	200	200	250	250
200	250	250	300	300
250	300	300	400	>600
300	400	400	>600	—
400	500	>600	—	—

Key: (1). and more. (2). Fuse link with rated current of smaller value, a. (3). Fuse link with rated current of larger value, a.

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In view of the probable deviations of the parameters of inserts from fixtures at their production, and also the different conditions for the work of safety device/fuse in the dependence on the place of its installation the guarantee of selectivity of protection presents known difficulties and requires the corresponding selection of the values of the rated currents of the fuse links in two adjacent sections of line, shielded by different safety devices/fuses.

Table 4-37 gives the relationships/ratios of the fuse links of safety devices/fuses PN2 to the larger and smaller values of rated current for the nets of especially critical designation/purpose in the dependence on the ratio of short-circuit current $I_к$ to the rated current smelting insert with smaller value $I_{в.м.}$ that show, what value of rated current smelting insert $I_{в.б}$ should be selected in order under any unfavorable conditions to ensure the necessary selectivity.

Since the corrected values are derived for guaranteeing the selectivity under the least favorable conditions, in the usual practice sufficient reliability is obtained, if we proceed from average/mean divergences from the standard characteristics. Necessary for these cases relationships/ratios are given in Table 4-38.

Safety fuses in electric systems above 1000V.

In the electric systems by voltage above 1000V for the protection of lines from the excess currents is applied relaying the information about which can be obtained from the appropriate literature. For the protection of transformers also are applied the safety fuses.

The information about the safety devices/fuses, utilized in the electric systems 6-35 kV, is given in Table 4-39.

The selection of safety device/fuse in depending on the power of the shielded installation can be produced on Table 4-40.

Automatic switches and magnetic starters.

Overload protection is provided:

1) by the thermal releases of automatic switches (series AP-50, A-3100 and the like), that operate with delays of time, conversely dependent on the strength of current of the overloading;

2) by releases with the clockwork automatic switches (series AV) with the conversely dependent from the current characteristic;

3) by electromagnetic releases with time element, sufficient for decreasing the starting current of electric motor to the normal, the automatic switches of series AM and AS;

4) by thermal relays with the heating elements of the magnetic starters;

5) by releases with the hydraulic retarder of the automatic

switches of types AST and AK.

For the protection from the short circuit are applied automatic switches with the electromagnetic releases of momentary effect or with time element, which ensures the selectivity of action.

The automatic switches of series AV have two time differences: 0.25 and 0.4 or 0.4 and 0.6 s, and series AS and AM - three steps/stages: 0.18; 0.38 and 0.63 s.

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Table 4-39. Technical specifications of the power safety devices/fuses of types ПК, ПКН, ПКЭ and ПКУ.

(1) Тип предохранителя	(2) Номинальное напряжение, кв	(3) Наибольший номинальный ток патрона, а	(4) Наименьший отключаемый ток в долях номинального	(5) Предельный ток отключения, ка: (6) симметричная составляющая	(7) с учетом апериодической составляющей	(8) Наибольшая разрывная мощность (трехфазная), Мва	(9) Наибольший пик тока при отключении предельного тока к. з., ка
ПК, ПКН, ПКЭ	6	7,5 30	(10) Не ограничен	20	30	200	6,7 6,7
		75 150 300	1,3	20	30	200	14 25 35
	10	7,5 30	(10) Не ограничен	12	18	200	5,5 5,5
		50 100 200	1,3	12	18	200	8,6 15,5 24
	35	10 20	(10) Не ограничен	3,5	5	200	1,8 2,8
		40	3	3,5	5	200	4,2
ПКУ	6	8 20 50 100 300	— — —	34 34	— —	350 350	6 6 14 25 35
	10	8 20 40 75 150	—	20	—	350	5,5 5,5 8,6 15,5 24
	20	15 30 50	—	14,5	—	500	4 6 9,5
	35	8 20 40	—	8,25	—	500	2 4 5,2

Key: (1). Type of fuse. (2). Nominal voltage, kV. (3). Greatest rated current of receptacle, a. (4). Smallest disconnected current in portions of nominal. (5). Limiting current of cutoff/disconnection, kA. (6). Symmetrical component. (7). taking into account aperiodic component. (8). Greatest breaking capacity (three-phase), MVA. (9). Greatest current spike with cutoff/disconnection of limiting current short circuit, kA. (10). It is unconfined.

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For guaranteeing the selectivity in the systems of the electric systems, shielded by automatic switches of the type indicated, smallest time element is established/installed in the electrical receiver.

The simultaneous protection of lines from the overloading and the short circuit is realized by a use/application of the combined releases, which consist of two elements/cells: one - for overload protection and another - for the protection from short circuit.

Technical data of the releases of automatic switches they are given in Table 4-41-4-45.

Technical specifications of the heating elements of the thermal

relays of the magnetic starters of series P, adjusted on the branchings to the electrical receivers, are shown in Table 4-46.

Data incorporated to the magnetic starters of series PA of thermal relays are given in Table 4-47. Tables 4-48 and 4-49 give technical specifications of the switches of types AST and AK.

The rated current of the shielding from the overloading thermal release or release with the hydraulic retarder of automatic switch and heating element of the thermal relay of magnetic starter $I_{н.т}$ is selected only on the prolonged calculated current of the line:

$$I_{н.т} \geqslant I_{дл}. \qquad (4\text{-}11)$$

Table 4-40. Selection or safety devices/fuses for the protection of the installations of three-phase alternating current 6-35 kV.

(1) Номинальный ток установки, а	(2) Номинальный ток плавкой вставки предохранителя, а	(3) Номинальная трехфазная мощность, ква, защищаемой установки при напряжении, кв		
		6	10	35
0,5	2,0	5	10	—
1,0	3,0	10	20	50
1,9	5,0	20	30	100
3,0	7,5	30	50	180
5,0	10	50	75	—
8,0	15	75	100	320
10	20	100	180	560
14,5	30	135	240	—
20	40	180	320	1 000
30	50	320	560	—
54	75	560	750	—
70	100	750	1 000	—
100	150	1 000	1 500	—
145	200	1 500	2 500	—
210	300	2 000	—	—

Key: (1). The rated current of installation, A. (2). Rated current by smelting insert of safety device/fuse, A. (3). Nominal three-phase power, kVA, shielded installation with voltage, kV.

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The rated current of the electromagnetic or combined release of automatic switches $I_{н.э}$ is selected also on the prolonged calculated current of the line:

$$I_{н.э} \geq I_{дл}, \quad (4\text{-}12)$$

and the spill current (cutoff) of electromagnetic or combination release $I_{ср.э}$ is checked using the maximum short-term current of line from the relationship/ratio

$$I_{ср.э} \geq 1{,}25 I_{кр} \quad (4\text{-}13)$$

(for the branching to single electric motor the maximum short-term

current of line is equal to the starting current of electric motor

Coefficient of 1.25 in formula (4-13) considers inaccuracy in the determination of the maximum short-term current of line and spread of the characteristics of the electromagnetic releases of automatic machines. For the majority of automatic machines the value of this coefficient provides the impossibility of the false cutoff/disconnection of line during launching/starting of electric motors, since the spread of the characteristics of automatic machines does not exceed +-15o/c. For the automatic machines of the type A3110, the spread of characteristics of which reaches value +-30o/c, coefficient value in formula (4-13) should be taken as the equal to 1.5.

The spill current of the release of automatic switch with the adjustable conversely dependent on the current characteristic is determined from the formula

$$I_{ср.р} \leq 1.25 I_{дл}. \qquad (4\text{-}14)$$

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Table 4-41. Technical specifications of the maximum releases of the automatic switches of series AV (nominal voltages 500V of alternating and 460V direct current).

(1) Тип автомата	(2) Номинальный ток автомата, а	(3) Номинальный ток катушки максимального расцепителя, а	(4) Уставка тока срабатывания максимальных расцепителей, а	
			(5) на шкале обратно зависимой от тока характеристики	(6) на шкале не зависимой от тока характеристики (отсечка)
АВ4Б	400	100	—	100, 150, 200
		150	—	150, 225, 300
		250	—	250, 375, 500
		400	—	400, 600, 800
АВ4Н	400	120	150, 250	960, 1 300
АВ4С		150	190, 300	1 200, 1 650
АВ4НВ		200	250, 400	1 600, 2 200
АВ4СВ		250	310, 500	2 000, 2 750
		300	375, 600	2 400, 3 300
		400	500, 800	3 200, 4 400
АВ10Б	1 000	600	—	600, 900, 1 200
		800	—	800, 1 200, 1 600

Table 4-4. cont.

AB10Б	1 000	1 000	—	1 000, 1 500, 2 000
AB10БВ	800	600 800	— —	600, 900, 1 200 800, 1 200, 1 600
AB10H AB10C	1 000	500 600 1 000 1 800	625, 1 000 750, 1 200 1 100, 1 600 1 500, 2 000	4 000, 5 500 4 800, 6 600 6 000, 8 000 8 000, 10 000
AB10HB AB10CB	750	500 600 750	621, 1 000 750, 1 200 1 000, 1 600	4 000, 5 500 4 800, 6 600 6 000, 8 000
AB15Б	1 500	1 000 1 500	— —	1 000, 1 500, 2 000 1 500, 2 200, 3 000
AB15БВ	1 150	800 1 150	— —	800, 1 200, 1 600 1 000, 1 500, 2 000
AB15H AB15C	1 500	1 000 1 200 1 500	1 250, 2 000 1 500, 2 400 1 800, 3 000	8 000, 10 000 8 000, 10 000 8 000, 10 000
AB15HB AB15CB	1 150	800 1 150	1 000, 1 600 1 450, 2 300	8 000, 10 000 8 000, 10 000
AB20Б	2 000	1 500 2 000	— —	1 500, 2 000, 3 000 2 000, 3 000, 4 000
AB20БВ	~1 500 —2 000	~1 000 1 500 —2 000	— — —	1 000, 1 500, 2 000 1 500, 2 200, 3 000 2 000, 3 000, 4 000
AB20H AB20C	2 000	1 000 1 200 1 500 2 000	1 250, 2 000 1 500, 2 400 1 800, 3 000 2 500, 4 000	8 000, 10 000 80 000, 10 000 9 000, 10 000 8 000, 10 000
AB20HB AB20CB	~1 500 —2 000	1 000 1 200 1 500 —2 000	1 250, 2 000 1 500, 2 400 1 800, 3 000 2 500, 4 000	8 000, 10 000 8 000, 10 000 8 000, 10 000 8 000, 10 000

Key: (1). Type of automatic machine. (2). Rated current of automatic machine, A. (3). Rated current of coil of maximum release, A. (4). Settings of spill current of maximum releases, A. (5). on scale of conversely dependent on current characteristic. (6). on scale of not dependent on current characteristic (cutoff).

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Table 4-42. Technical of the releases of the automatic switches of series A-3100 (nominal voltages 500 V of alternating and 220 V direct current).

(1) Тип автомата	(2) Номинальный ток автомата, а	(3) Тепловой и комбинированный расцепители		(4) Электромагнитный расцепитель		
		(5) Номинальный ток, а	(6) Уставка тока мгновенного срабатывания, а	(5) Номинальный ток, а	(7) Уставка тока мгновенного срабатывания	
					(8) переменный ток, а	(9) постоянный ток, а
A3161 A3162 A3163	50	15, 20, 25 30, 40, 50	—	—	—	—
A3114 A3113	100	15 20 25 30 40 50 60 80 100	150 200 250 300 400 500 600 800 1 000	15 20 25 40 40 60 60 100 100	150 200 250 300 400 500 600 800 1 000	
A3124 A3123	100	15, 20, 25, 30 40, 50, 60 80, 100	430 600 800	30 100 100	—	430 600 800
A3134 A3133	200	120 150 200	840 1 050 1 400	200 200 200	840 1 050 1 400	
A3144 A3143	600	250 300 400 500 600	1 750 2 100 2 800 3 500 4 200	600 600 600 600 600	1 750 2 100 2 800 3 500 4 200	

Notes: 1. The multiplicity of the spill current of the thermal release of the automatic switches of series A3160 composes 1.35, and all remaining types 1.45.

2. During setting up of automatic switches in closed cabinets, for example series PR9000, conditions of cooling switches deteriorate

and rated current of switch and thermal or combined release must descend to 80-90c/o (in average/mean 85o/o) of nominal values, indicated in Table 4-42.

Key: (1). Type of automatic machine. (2). Rated current of automatic machine, A. (3). Thermal and combined release. (4). Electromagnetic release. (5). Rated current, A. (6). Setting of current of instantaneous functioning, A. (7). Setting of current of instantaneous functioning. (8). alternating current, A. (9). direct current, A.

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Table 4-43. Technical specifications of the releases of the automatic switches of series AP50 (nominal voltages 380V of alternating current and 220V direct current, rated current 50A).

(1) Тип автомата	(2) Расцепитель максимального тока	(3) Номинальный ток расцепителя[1], *а*	(4) Пределы регулирования номинального тока уставки теплового расцепителя[1], *а*	(5) Ток срабатывания электромагнитного расцепителя (отсечка)[1], *а*	
				(6) при переменном токе частотой 50 *гц*	(7) при постоянном токе
АП50-3МТ АП50-2МТ	(8) Комбинированный	1,6 2,5 4	1—1,6 1,6—2,5 2,5—4	11 17,5 28	14 22 36
АП50-3М АП50-2М	(9) Элекромагнитный	6,4 10	4—6,4 6,4—10	45 70	57 90
АП50-3Т АП50-2Т	(10) Тепловой	16 25 40 50	10—16 16—25 25—40 30—50	110 175 280 350	140 220 352 440

Note. Multiplicity of the spill current of thermal release 1.25-1.35.

Key: (1). Type of automatic machine. (2). Release of maximum current. (3). Rated current of release [1], A.

FOOTNOTE [1]. It relates to all performances of the automatic switches of series AP50. ENDFOOTNOTE.

(4). Ranges of adjustment of rated current of setting of thermal release [2], A.

FOOTNOTE [2]. It relates to the performances 2MT, 3MT, 2T and 3T. ENDFOOTNOTE.

(5). Spill current of electromagnetic release (cutoff) [3], A.

FOOTNOTE [3]. It relates to the performances 2MT, 3MT, 2M and 3M. ENDFOOTNOTE.

(6). with alternating current by frequency of 50 Hz. (7). with direct current. (8). Combined. (9). Electromagnetic. (10). Thermal.

Table 4-44. Technical specifications of the releases of the single-pole automatic switches of series AO-15 and AB-25.

(1) Тип автомата и расцепителя	(2) Номинальное напряжение, в	(3) Номинальный ток автомата, а	(4) Номинальный ток расцепителя, а	(5) Кратность тока срабатывания электромагнитного расцепителя
АБ-25 (6) тепловой	220 (7) переменного тока	25	15, 20, 25	—
АО-15МТ (8) комбинированный	220 (9) постоянного и переменного тока	15	1; 1,2; 1,5; 2; 2,5; 3; 4; 5; 6; 8; 10; 12; 15	10—15
АО-15ЭМ (10) электромагнитный	(11) То же	15	1; 1,2; 1,5; 2; 2,5; 3; 4; 5; 6; 8; 10; 12; 15; 20	1,3
АО-15М (10) электромагнитный	220 (9) постоянного и переменного тока	15	1; 1,2; 1,5; 2; 2,5; 3; 4; 5; 6; 8; 10; 12; 15; 20	2—10
АО-15Т (6) тепловой	(11) То же	15	1,5; 2,5; 4; 6; 10; 15; 20; 25	—

Note. Multiplicity of the spill current of thermal release 1.35.

Key: (1). Type of automatic machine and release. (2). Nominal voltage, in. (3). Rated current of automatic machine, A. (4). Rated current of release, A. (5). Multiplicity of spill current of electromagnetic release. (6). thermal. (7). alternating current. (8). combined. (9). direct and alternating current. (10). electromagnetic. (11). Then.

Table 4-45. Technical specifications of the maximum releases of automatic air circuit breakers of series AS, AG and AM to 400V alternating and 220V direct current.

(1) Тип автомата	(2) Номинальный ток автомата, а	(3) Номинальный ток максимального расцепителя, а	(4) Кратность уставок тока срабатывания по отношению к номинальному току			
			(5) Пределы уставок тока срабатывания	(6) Расцепитель зоны к. з.	(7) Комбинированный расцепитель	
					(8) зона к. з.	(9) зона нагрузки
АС	800	75, 130, 190, 260, 375, 500, 625, 800	2—4,5	—	—	—
	1 500	1 250, 1 500 2 000, 2 500				
АГ	800	150, 300, 400, 500, 600, 800	2—3	—	—	—
	1 000	1 000, 1 250, 1 500				
АМ	800	130, 190, 260, 375, 500, 625, 800	—	(10) При переменном токе 2—8	(10) При переменном токе 3—8	1,55—2
	1 500 2 500	1 250, 1 500, 2 000, 2 500	—	(11) При постоянном токе 2—4,5	(11) При постоянном токе 3—4,5	

Note. The automatic machines of series AS, AG and AM for guaranteeing the selectivity of protection can be inclined to one of three steps/stages of triggering time: 0.18; 0.38 and 0.63 s.

Key: (1). Type of automatic machine. (2). Rated current of automatic machine, A. (3). Rated current of maximum release, A. (4).

Multiplicity of settings of spill current in realtion to rated current. (5). Limits of settings of spill current. (6). Release of zone short circuit. (7). Combined release. (8). zone short circuit. (9). zone of load. (10). With alternating current. (11). With direct current.

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Table 4-46. Technical specifications of the heating elements of the thermal relays of the magnetic starters of series P (nominal voltage of up to 500V).

(1) № элементов	(2) Номинальные токи элементов пускателей 2-й величины, а	(1) № элементов	(3) Номинальные токи элементов пускателей		(1) № элементов	(5) Номинальные токи элементов пускателей	
			(4) 2-й величины, а	(4) 3-й величины, а		(4) 4-й величины, а	(4) 5-й величины, а
1	0,64—0,73	20	3,9—4,2	6,0—6,5	—	—	—
2	0,73—0,80	21	4,2—4,7	6,5—7,0	43	31—34	—
3	0,80—0,90	22	4,7—5,2	7,0—7,7	44	34—37	—
4	0,9—1,0	23	5,2—5,8	7,7—8,5	45	37—41	—
5	1,0—1,1	24	5,8—6,3	8,5—9,5	46	41—45	—
6	1,1—1,2	25	6,3—7,2	9,5—10,5	47	45—50	—
7	1,2—1,3	26	7,2—8,0	10,5—11,5	48	50—55	—
8	1,3—1,4	27	8,0—8,9	11,5—12,5	49	55—60	—
9	1,4—1,5	28	8,9—9,7	12,5—13,5	50	60—65	—
10	1,5—1,7	29	9,7—10,7	13,5—15,0	51	65—70	—
11	1,7—1,9	30	10,7—11,6	15,0—16,5	52	70—77	—
12	1,9—2,1	31	11,6—12,8	16,5—18,0	53	77—85	—
13	2,1—2,3	32	12,8—13,8	18,0—20,0	54	85—95	—
14	2,3—2,5	33	13,8—15,2	20,0—22,5	55	95—105	—
15	2,5—2,7	34	15,2—16,8	22,5—25,0	56	—	66—65
16	2,7—2,9	35	16,8—18,3	25—28	57	—	65—70
17	2,9—3,3	36	18,3—20,0	28—31	58	—	70—77
18	3,3—3.6	37	—	31—34	59	—	77—85
19	3,6—3,9	38	—	34—37	60	—	85—95
—	—	39	—	37—41	61	—	95—105
—	—	40	—	41—45	62	—	105—115
—	—	41	—	45—50	63	—	115—125
—	—	—	—	—	64	—	125—135
—	—	—	—	—	65	—	135—150

Note. The multiplicity of the spill current of thermal relay

with respect to the rated current of heating element is equal to 1.2. Thermal relays allow/assume the regulated values of spill current.

Key: (1). elements/cells. (2). Rated currents of elements/cells of starters of 2nd value, A. (3). Rated currents of elements/cells of starters. (4). cf value, A.

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Table 4-47. Technical data of thermal relays, incorporated into the magnetic starters of series Pa (nominal voltage 500V).

(1) Величина пускателя	(2) Наибольшая мощность электродвигателя при напряжении 380 в, квт	(3) Тип теплового реле	(4) Исполнение пускателя					
			(5) открытое			(6) защищенное		
			(7) Ток уставки тепловых реле, а					
			(8) номинальный	(9) нулевая уставка	(10) диапазон регулирования	(8) номинальный	(9) нулевая уставки	(10) диапазон регулирования
3	17	ТРП-32	40	32	24—40	40	32	24—40
4	28	ТРП-60	56	50	38—56	56	44	33—56
5	55	ТРП-150	115	120	90—115	115	104	78—115
5	55	ТРП-150	115	70	52,5—87,5	115	60	45—75
6	75	ТРП-150	150	130	97,5—150	140	125	94—140

Notes: 1. Zero setting corresponds to the zero position of the indicator of the scale of the settings of thermal relay.

2. Multiplicity of spill current of thermal relay with respect to rated current composes 1.2.

3. Scale of relay is designed for ambient temperature of +35°C. At a lower ambient temperature trip point must be increased of the calculation one scale division on 10°C.

Key: (1). Value of starter. (2). Highest efficiency of electric motor

with voltage 380V, kW. (3). Type or thermal relay. (4). Performance of starter. (5). opened. (6). shielded. (7). Current of setting of thermal relays, A. (8). nominal. (9). zero setting. (10). range of control.

Table 4-48. Technical specifications of the automatic switches of alternating current AST.

(1) Тип автомата	(2) Номинальное напряжение, в	(3) Номинальный ток, а	(4) Шкала номинальных токов расцепителей, а
АСТ-2 АСТ-3	380	25	0,3; 0,4; 0,5; 0,63; 0,8; 1; 1,25; 1,6; 2; 2,5; 3,2; 4; 5; 6,3; 8; 10; 12,5; 16; 20; 25

Note; 1. Automatic switches are made in two-pole (AST-2) and tripolar (AST-3) versions.

2. Electromagnetic releases of switch are equipped with hydraulic retarder, which ensures with multiplicity of current, equal to 1.2 nominal ones, time element not more than 20 min, with multiplicity of current from 6 to 15 6-15 s and with multiplicity 14 momentary effect (cutoff).

Key: (1). Type of automatic machine. (2). Nominal voltage, in. (3). Rated current, A. (4). Scale of rated currents of releases, A.

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Table 4-49. Technical specifications of automatic switches of the type AK-63.

(1) Тип автомата	(2) Номинальное напряжение, в	(3) Шкала номинальных токов расцепителей, а
АК-63	~440 —240	0,63; 0,8; 1; 1,25; 1,6; 2; 2,5; 3,2; 4; 5; 6,3; 8; 10; 12,5; 16; 20; 25; 32; 40; 50; 63

Notes: 1. Automatic switches are made in the two-pole and tripolar performances.

2. Electromagnetic of release of switch have two modifications: type M - instantaneous and type MG - with hydraulic retarder.

3. Releases are made with multiplicity of current of cutoff 14 for alternating current and 5 - for direct current. Releases of the type M are made for alternating current also with the multiplicity of current 3.

4. Releases of type MG have triggering time with multiplicity of current 1.2 not more than 20 min and with multiplicity 6 from 3 to 20 s.

Key: (1). Type of automatic machine. (2). Nominal voltage, in. (3).

Scale of rated currents cf releases, A.

4-3. Selection of the sections cf wires and cables.

The section of wires and cables by voltage cf up to 1000V according to the conditicn neatings are defined from tables 4-1-4-20, 4-22 and 4-27-4-31 in depending on computed value of the permissible constant load under standard conditions cf the separator, defined as high value of two relaticnships/ratios:

according to the conditicr cf heating by the prolonged calculated current

$$I_{д.д} \geq \frac{I_{дл}}{K_п} \qquad (4\text{-}15)$$

and according to conformity condition to the selected apparatus of the maximum current protection

$$I_{д.д} \geq \frac{K_з I_з}{K_п}, \qquad (4\text{-}16)$$

where $K_п$ - correction factor to the conditions of the wiring and cables;

$K_з$ - multiplicity of the permissible prolonged current for the wire or the cable with respect to the rated current or the spill current of the shielding apparatus;

$I_з$ - rated current or spill current of shielding element/cell, A.

Under standard conditions for separator $K_з=1$ and relationship/ratio (4-15) and (4-16) they are simplified:

$$I_{в.н} \geq I_{н.н}; \qquad (4\text{-}17)$$

$$I_{в.н} \geq K_з I_з \qquad (4\text{-}18)$$

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Values $K_з$ and $I_з$ are determined from table 4-50 in depending on a character of network/grid, type of the wire insulation and cables and conditions of their separator.

According to Section of III PUE the networks/grids are divided into two groups: the networks/grids which must be shielded from the overloading and the currents short circuit, and the networks/grids, shielded only from the currents short circuit.

According to § III-1-9 PUE to overload protection they are subject:

1) the networks/grids indoors, made opened by the laid unprotected isolated/insulated conductors with the combustible shell;

2) the networks/grids indoors, made by shielded conductors, the

conductors, laid in the tubes, not combusted structures, etc., in the following cases:

A. Lighting systems in the habitable and public buildings, the commercial locations, official-everyday locations of industrial enterprises, switching on networks/grids for the everyday and movable electrical receivers, and also in the flammable production locations.

B. Power networks/grids in industrial enterprises, habitable and public buildings, commercial locations in cases when under conditions for technological process or conditions of work of network/grid can appear prolonged overloading of wires and cables.

C. Of networks/grids of all forms in dangerously explosive placements and dangerously explosive external settings up independent of conditions of technological process or mode/conditions of work of network/grid.

All remaining networks/grids do not require overload protection and are shielded only from the currents short circuit.

If the permissible prolonged current load, found from (4-16) or (4-18) in accordance with the requirements § III-1-10 of PUE, does not coincide with the data of the tables of the permissible loads, is

permitted the use/application of a conductor of the nearest smaller section, but not smaller than this is required during the determination of the permissible load from (4-15) and (4-17). The sections of wires and cables for the branching to the engine with short-circuited rotor in all cases are selected in accordance with (4-15) or (4-17), in which the prolonged calculated current of line is equal: for the nonexplosive locations - to the rated current of engine, and for the dangerously explosive ones - 125o/o of the rated current of engine by voltage or up to 1000V. The selected section of wire or cable must be checked on (4-16) or (4-18) § III-1-7 by PUE for the networks/grids, shielded only from short circuit.

In all cases must be provided reliable cutoff/disconnection with shielding apparatuses the single-phase short circuit, which occurred at the most distant points of network/grid. This condition is satisfied, if the multiplicity of current single-phase short circuit in the networks/grids by dully grounded neutral is not less than 3 with respect to the rated current by smelting the insert of safety device/fuse and the rated current of the release of the automatic switch, which has the conversely dependent on the current characteristic, and is not less $1.1K_p$ with respect to the spill current of the automatic switch, which has only electromagnetic release (K_p - the coefficient, which calculates the spread of the characteristics of release on the basis of the data of plant).

For the networks/grids, run in the dangerously explosive locations, the permissible multiplicities of current short circuit increase to value of 4 with respect to the rated current by smelting the insert of safety device/fuse and to 6 with respect to the rated current of the release of automatic switch with the conversely depending on the current characteristic.

Table 4-50. Minimum multiplicities of the permissible current loads cn the wires and the catlas with respect to the rated currents, the pickup currents or the currents cr the setting cf shielding apparatuses.

(3) Значение тока защитного аппарата $I_з$	(1) Кратность допустимых длительных токов $K_з$			
	(2) Сети, для которых защита от перегрузки обязательна (ПУЭ, § III-1-10)			(8) Сети, не требующие защиты от перегрузки (ПУЭ, § III-1-7)
	(4) Проводники с резиновой и аналогичной по тепловым характеристикам изоляцией		(7) Кабели с бумажной изоляцией	
	(5) Взрыво- и пожароопасные помещения, жилые, торговые помещения и т. п.	(6) Невзрыво- и непожароопасные производственные помещения промышленных предприятий		
(9) Номинальный ток плавкой вставки предохранителей	1,25	1,0	1,0	0,33
(10) Ток уставки автоматического выключателя, имеющего только максимальный мгновенно действующий расцепитель	1,25	1,0	1,0	0,22
(11) Номинальный ток расцепителя автоматического выключателя с нерегулируемой обратно зависимой от тока характеристикой (независимо от наличия или отсутствия отсечки)	1,0	1,0	1,0	1,0
(12) Ток трогания расцепителя автоматического выключателя с регулируемой обратно зависимой от тока характеристикой (при наличии на автоматическом выключателе отсечки кратность тока ее не ограничивается)	1,0	1,0	0,8	0,66

Key: (1). Multiplicity ci the permissible prclonged currents. (2). Networks/grids, for which overlcad protecticn is necessary. (3). Value of current of shielding apparatus. (4). Conductors with rubber and analogous in thermal characteristics insulation. (5). Explosicn- and flammable locaticns, habitable, commercial lccations, etc. (6).

Nonexplosion and fireproof production locations of industrial enterprises. (7). Cables with paper insulation. (8). Networks/grids, which do not require overload protection. (9). Rated current by smelting insert of safety devices/fuses. (10). Current of setting of automatic switch, which has only maximum instantly operating release. (11). Rated current of release of automatic switch with fixed conversely dependent on current characteristic (independent of presence or absence of cutoff). (12). Pickup current of release of automatic switch with adjustable conversely dependent on current characteristic (when, on automatic switch, cutoff is present, multiplicity of its current is not limited).

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For the networks/grids, shielded only from the currents short circuit, the overestimate of the currents of the fuse links of safety devices/fuses and settings of the releases of automatic machines in comparison with the values, regulated in Table 4-50, is allowed/assumed in the necessary cases, for example for the reliable tuning out from the currents of the self-start of engines, when the multiplicity of current short circuit has a value not less than 5 with respect to the ratec current by smelting the insert of safety device/fuse and not less than 1.5 with respect to the spill current of the electromagnetic release of automatic machine.

Checking the conditicns fcr tne reliable functioning of protectors with the shcrt circuit is given in Section 7.

The sections of wires and caoles of line by voltage above 1000V according to the conditicns of heating are determined on the prolonged calculated currents according to (4-15) or (4-17).

Example 4-4. Trunk line of the power network/grid 380/220V of industrial enterprise it supplies the group cf engines. Line is made by armored triple-core caole with the aluminum veins/strands and rubber insulation and runs itself in the location with the temperature of surrounding air cf +25°C. Prolcnged calculated current cf line 100 and also short-term current with the self-start cf engines 500 A. Conditions of tne self-start of electric motors the lungs.

To determine the rated current of the fuse links, which shield the line of safety devices/fuses cf the type PN-2, and to select the section of cable under the fcllcwing conditions:

1. Line passes to ncnexplosive and fireprccf production locaticn and it must be shielded frcm the cverlcading.

2. Line passes to flammable location and it must be shielded from overloading.

3. Line must be shielded only from short circuit.

Solution. We determine the value of the rated current of the fuse links, which shield the line of safety devices/fuses, according to the condition of prolonged current from (4-5):

$$I_{в} \geqslant 100 \ A$$

and according to the condition of short-term current from (4-8):

$$I_{в} \geqslant \frac{500}{2.5} = 200 \ A.$$

Decisive when selecting of the fuse links proves to be overshooting with the self-start of electric motors. We stop on the safety devices/fuses of the type PN-2-250/II with the fuse links to rated current 200 and (see Table 4-36).

For the selection of the section of cable we use simplified formulas (4-17) and (4-18), since the conditions of its separator are

normal (temperature of surrounding air of +25°C).

The permissible lcad on the cable according to the condition of heating by prolonged calculated current is determined from (4-17):

$$I_{д.д} \geqslant 100 \ A$$

also, according to conformity condition for the section of cable by smelting to the insert of the safety device/fuse from (4-18), in which the values of coefficient $K_з$ for each of the versions in question will be different.

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1. For india-rubber cable, shielded from overloading and passing in nonexplosive and fireproof place, from Table 4-50

$$K_з = 1,0.$$

The permissible constant lcad on the cable is determined on (4-18):

$$I_{д.д} \geqslant 1 \cdot 200 = 200 \ A.$$

On Table 4-4 we select for triple-core cable with the aluminum veins/strands and the rubber insulation with the separator in the air section 120 mm² for which the permissible lcad is equal to 200 A.

2. For cable, which passes in flammable lccation and shielded from overloading, analcgcusly we will obtain:

$$K_{\text{з}}=1{,}25;$$
$$I_{\text{н.к}}\geqslant 1{,}25\cdot 200=250 \text{ A}.$$

The section of cable we take as the equal to 150 mm²; the permissible constant load for it is equal to 235 A. We use indication PUE about that which during checking of the conformity of the sections of wires and cables to the characteristic of shielding apparatus is allowed/assumed to select the conductors of the nearest smaller section how it is required on the calculated current.

3. For cable, shielded cnly from short circuit, we will obtain

$$K_{\text{з}}=0{,}33;$$
$$I_{\text{н.к}}=0{,}33\cdot 200=66 \text{ A}.$$

In this case the section of cable 50 mm² is determined by the condition of heating by prolonged current (permissible load 110 A).

Example 4-5. Fig. 4-1 depicts the schematic of the section of the power network/grid of industrial enterprise voltage 380/220V. From the busbars of the distributing frame obtains feed the power assembly with the automatic switches, to which are connected six asynchronous engines with short-circuited rotor. Electric motors 3

and 4 are established/installed in the dangercusly explosive location cf class V1a, remaining engines, distributicn pcints and starting/launching equipment - in the locaticns with the normal medium.

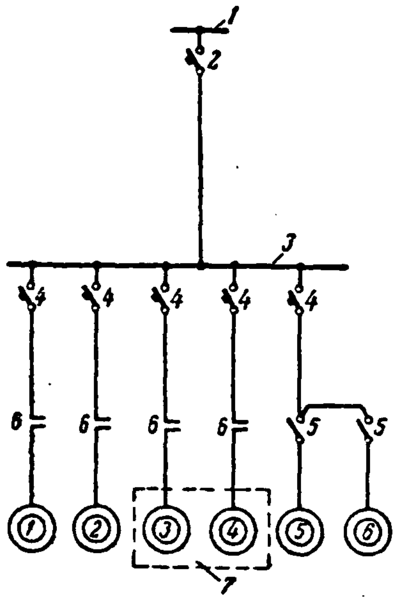

Fig. 4-1. Schematic of network/grid for example 4-5. 1 - busbar 380/220V of the distributing frame; 2 - automatic switch of the type AV-4S; 3 - busbar of the distributive power point/item of series PR 9000; 4 - automatic switch of the type A3124; 5 - push-on starter of the type PNV-34; 6 - magnetic starter of the type Pa; 7 - dangerously explosive location.

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Technical specifications of engines are shown in Table 4-51. Engine power rating excludes the possibility of the prolonged overloadings; the condition for their launching/starting moderate/mild, possibility

of the self-start of large power motors it is excluded.

One of engines 1 or 2 is always located in the reserve; remaining engines can work simultaneously.

Trunk line from the distributing frame to the power point/item is shielded by a selective automatic switch of the type AV-4S to 500V and 400 and with the maximum releases with the conversely dependent on the current characteristic and the cutoff with time element of 0.6 s. Lines from the power point/item to the electric motors are shielded by the established/installed in the cabinet of the type PR9262-137 automatic switches of the type A3124 to 500V and 100 A with the combined releases.

Trunk line from the distributing frame to the power point/item is made by triple-core cable with the paper insulation of brand AABG, lines to the electric motors - by a rubber-covered wire APRTC and (for the dangerously explosive location) PRTC in the steel tubes. Entire wiring passes to locations with the temperature of air of +25°C.

It is necessary to determine the rated currents of the releases of automatic switches and to select the sections of wires and cable from the condition for heating and conformity to the currents of the

releases of automatic switches.

Solution. Since the temperature of air in the location is equal to +25°C, then correction factor $K_n=1$ and when selecting of the sections of wires and cables in the condition of heating one should be guided (4-17) and (4-18).

Line to electric motor 1. We select the combined release of automatic switch A3124 according to the condition of the prolonged current of line, equal in this case to the rated current of electric motor 1 (see Table 4-51).

According to note by 2 to Table 4-42 when selecting of the release, built in the closed cabinet of automatic switch, it is necessary to consider correction factor on the order of 0.85. Taking into account the aforesaid, we select the release of automatic switch according to the condition of the prolonged current of line from the relationship/ratio

$$I_{н.э} \geqslant \frac{73.1}{0.85} = 86\ A.$$

On Table 4-42 we select the combined release with rated current 100 A and also by the current of instantaneous functioning 800 A.

We check possibility of the false response of automatic switch during launching/starting of engine 1 on (4-13):

$$I_{ср.э} \geq 1{,}25 \cdot 432 = 540;\ 800\ A > 540\ A.$$

According to indications of PUE for the lines to the electric motor in the nonexplosive location the section is selected on the rated current of engine from (4-17) with the subsequent checking on (4-18), on the basis of the condition of circuit protection only from short circuit.

Computed value of the permissible current of line is equal to:

$$I_{н.д} \leq 73{,}1\ A$$

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On table 4-2 we select three-strand wire with the aluminum veins/strands of brand АПВТС by section 35 mm² for which the permissible load is equal to 75 A.

We check the conformity of the selected section of wire to the apparatus of current protection. Since the automatic switches of series A3100 do not have current control of setting, the multiplicity

of the permissible current of line must be determined with respect to the rated current of release, equal in our case $I_s=100$ A. Through table 4-50 we find value K_s for the networks, which do not require overload protection for the rated current of the release of automatic switch with the fixed conversely dependent on the current characteristic:

$$K_s=1.$$

After substituting numerical values in relationship/ratio (4-18):

$$75 \overset{(1)}{a} < 1 \cdot 100 = 100 \overset{(1)}{a}$$

Key: (1). A.

we see that the required condition is not satisfied.

We stop in the section of wire 50 mm², for which condition (4-18) is satisfied:

$$105 \overset{(1)}{a} > 100 \overset{(1)}{a}$$

Key: (1). A.

For the remaining lines the results of calculation are given in Table 4-52 or are given below the explanations, connected with the special features/peculiarities of each of them.

Lines to electric motor 3. Line to electric motor 3 has the

following special features/peculiarities. Engine 3 is established/installed in the dangerously explosive location of class V1a, in connection with which:

1) for the calculated current when selecting of the section of line is accepted the rated current of engine, increased 1.25 times;

2) in the dangerously explosive location of class V1a is not permitted the use/application of wires and cables with the aluminum veins/strands, consequently line from the magnetic starter to the electric motor must be performed by wire with the copper veins/strands (brand PRTO).

Line to electric motor 4. The section of wire PRTO from the magnetic starter to engine 4 is accepted by the equal to 2.5 mm², since smaller section for the power networks in the dangerously explosive locations is not allowed/assumed (see Table 1-10).

Table 4-51. Technical specifications of electric motors on example 4-5.

(1) Тип	(2) Номинальная мощность, квт	(3) Номинальный ток, а	(4) Кратность пускового тока	(5) Пусковой ток, а
A2-81-4	40	73,1	5,9	432
A2-81-4	40	73,1	5,9	432
MA-145-2/6	34	69	6,5	448
MA142-2/8	4	10,5	5	52,5
AO2-41-4	4	7,7	5,7	43,8
AO2-41-4	4	7,7	5,7	43,8

Key: (1). Type. (2). Nominal power, kW. (3). Rated current, A. (4). Multiplicity of starting current. (5). Starting current, A.

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Line to electric motors 5 and 6. The calculated current of line is determined by the sum of the currents of engines 5 and 6.

Trunk line. The prolonged calculated current load of line according to the condition of an example is determined by the sum of the currents of all electric motors, with exception of current of one of electric motors 1 or 2:

$$I_{\text{дл}}=73{,}1+69+10{,}5+2\cdot 7{,}7=168 \text{ A}.$$

Short-term current load is determined on (4-9) from the condition of launching/starting engine 3, which has the jerk/impulse

of starting current greatest:

$$I_{нр}=448+73,1+10,5+2\cdot 7,7=547 \text{ A}.$$

We select the electromagnetic release of automatic switch AV-4S according to the condition of the prolonged current of line from (4-12):

$$I_{н.э}\geqslant 168 \text{ A}.$$

On table 4-41 we select maximum release with the rated current 200 A. The setting of spill current we accept on the scale of dependent on the current characteristic 250 A and also on the scale of the not dependent on the current characteristic (cutoff with time element) of 1600 A.

We check the impossibility of the false response of automatic switch during launching/starting of electric motor 3 on (4-13):

$$1\,600>1,25\cdot 547=682 \text{ A}.$$

We determine the tabular value of the permissible prolonged current for the cable:

$$I_{н.д} \geq 168 \text{ A.}$$

On table 4-14 we select triple-core cable with the aluminum veins/strands to 3 kV by section 95 mm² for which the permissible load is equal to 190 A.

We check the conformity of the selected section of cable to the apparatus of current protection. Since the automatic switches of series AB have current control of setting on the scale of the conversely dependent on the current characteristic, the multiplicity of the permissible current of line must be determined with respect to spill current of release in this part of the characteristic, equal in our case $I_з=250$ A. Through table 4-50 we find value $K_з$ for the networks, which do not require overload protection, for the spill current of the release of automatic switch with the adjustable conversely dependent on the current characteristic:

$$K_з=0{,}66.$$

After substituting numerical values in (4-18):

$$190>0{,}66\cdot 250=165 \text{ A},$$

let us find that the required condition is satisfied.

Table 4-53-4-55 gives the permissible loads and the limiting

values of the rated currents of the fuse links of safety devices/fuses and rated currents of the thermal and combined releases of the automatic switches of series A310C for the wires and the cables for the voltage of up to 1000V with the aluminum veins/strands with the separator opened in the air or in the tubes during the continuous duty. Table 4-56 shows for the same wires and conditions of separator the permissible loads during the intermittent duty.

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Table 4-52. Table for the selection of releases and sections of wires and cables from example 4-5.

(1) Наименование линий	(2) Расчетный ток линии, а		(3) Номинальный ток расцепителя, а		(4) Уставка тока мгновенного срабатывания расцепителя, а		$K_в$	(5) Допустимая токовая нагрузка на провод (кабель), а		(13) Марка и сечение провода (кабеля), мм²
	(6) длительный	(7) кратковременный	(8) расчетный	(9) принятый	(10) расчетная	(11) принятая		(10) расчетная	(12) фактическая	
(14) К электродвигателю 1	73,1	432	86	100	540	800	1	100	105	АПРТО 3×50
К электродвигателю 2	73,1	432	86	100	540	800	1	100	105	АПРТО 3×50
(14) К электродвигателю 3:										
(15) 1) от силового пункта до пускателя	69	448	81,5	100	560	800	1	100	105	АПРТО 3×50
(16) 2) от пускателя до двигателя	86,3	—	—	—	—	—	1	100	100	ПРТО 3×35
(14) К электродвигателю 4:										
(15) 1) от силового пункта до пускателя	10,5	52,5	12,4	15	66	430	1	15	16	АПРТО 3×2,5
(16) 2) от пускателя до двигателя	13,1	—	—	—	—	—	1	15	21	ПРТО 3×2,5
(14) К электродвигателям 5 (16a) и 6 . . .	15,4	87,6	18	20	110	430	1	20	23	АПРТО 3×4
(17) Магистраль	168	547	168	200	682	1 600	0,66	168	190	ААБГ 3×95

Key: (1). Designation of lines. (2). Calculated current of line, A. (3). Rated current of release, A. (4). Setting of current of instantaneous functioning of release, A. (5). Permissible current load on wire (cable), A. (6). prolonged. (7). short-term. (8). calculated. (9). accepted. (10). calculated. (11). accepted. (12). actual. (13). Brand and section of wire (cable), mm². (14). To electric motor. (15). from power point/item to starter. (16). from starter to engine. (16a). and. (17). main line.

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Table 4-53. The maximum rated currents of the fuse links of inertia-free safety devices/fuses and the permissible constant loads for the wires and the cables with the aluminum veins/strands in the production nonexplosion and fireproof locations, in which is required circuit protection from the overloading.

(3) Сечение, мм²	(1) Открытая прокладка											(2) Прокладка в трубах							
	АПР	АПРГ	АПР, АПРГ	АПРГ, АВРГ				ААГ, ААБГ				АПРТО, АПРГ, АВРГ							
	(4) Нагрузка, а		(5) Ток вставки, а	(4) Нагрузка, а		(5) Ток вставки, а		(4) Нагрузка, а		(5) Ток вставки, а		(4) Нагрузка, а		(5) Ток вставки, а	(4) Нагрузка, а		(5) Ток вставки, а	
	(6) одножильные			(7) двухжильные	(8) трехжильные	(7) двухжильные	(8) трехжильные	(7) двухжильные	(8) трехжильные	(7) двухжильные	(8) трехжильные	(9) два одножильных	(10) три одножильных	(11) два и три одножильных	(12) один двухжильный	(13) один трехжильный	(7) двухжильные	(8) трехжильные
2,5	24	23	25	21	19	20		23	22	25		20	19	20	19	16	20	15
4	32	31	30	29	27	30		31	29	30		28	28	30	25	21	25	20
6	39	38	40	38	32	40	30	42	35	50		36	32	30	31	26	30	25
10	55	60	60	55	42	50	40	55	46	50		50	47	50	42	39	40	
16	80	75	80	70	60	60		75	60	80	60	60	60	60	62	54	60	
25	105	105	100	90	75	80		100	80	100	80	85	80	80	77	65	80	
35	130	130	120	105	90	100		115	95	120	100	100	95	100	96	77	80	
50	165	165	200	135	110	120		140	120	150	120	140	130	150	123	104	120	100
70	210	210	200	165	140	150		175	155	200	150	175	165	200	150	135	150	
95	255	250	250	200	170	200		210	190	200		215	200	200	189	166	200	
120	295	295	300	230	200	200		245	220	250		245	220	250	228	192	200	
150	340	340	350	270	235	250		290	255	300	250	275	255	250	—	—	—	
185	390	295	400	310	270	300		—	290	300		—	—	—	—	—	—	

Key: (1). Surface work. (2). Separator in tubes. (3). Section, mm². (4). Load, A. (5). Current of insert, A. (6). single-cable. (7). twin-cored. (8). three-strand. (9). two single-cable. (10). three single-cable. (11). two and three single-cable. (12). one twin-cored. (13). one three-strand.

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Table 4-54. The maximum rated currents of the fuse links of inertia-free safety devices/fuses and the permissible constant loads for the wires and the cables with the aluminum veins/strands (voltage of up to 1000V) in the explosion- and flammable locations and in the networks of the non-production locations, in which is required overload protection.

(3) Сечение, мм²	(1) Открытая прокладка											(2) Прокладка в трубах						
	АПР	АНРГ	АПР, АНРГ	АНРГ, АВРГ				ААГ, ААБГ				АПРТО, АНРГ, АВРГ						
	(4) Нагрузка, а		(5) Ток вставки, а	(4) Нагрузка, а		(5) Ток вставки, а		(4) Нагрузка, а		(5) Ток вставки, а		(4) Нагрузка, а		(5) Ток вставки, а	(4) Нагрузка, а		(5) Ток вставки, а	
	(6) одножильные			(7) двух-жильные	(8) трех-жильные	(7) двух-жильные	(8) трех-жильные	(7) двух-жильные	(8) трех-жильные	(7) двух-жильные	(8) трех-жильные	(9) два одно-жильных	(10) три одно-жильных	(11) два и три одно-жильные	(12) один двух-жильный	(13) один трех-жильный	(7) двух-жильные	(8) трех-жильные
2,5	24	23	20	21	19	15		23	22	20		20	19	15	19	16	15	
4	32	31	25	29	27	20		31	29	30		28	28	25	25	21	20	
6	39	38	30	38	32	30	25	42	35	40		36	32	25	31	26	25	
10	55	60	50	55	42	40		55	46	50		50	47	40	42	39	30	
16	80	75	60	70	60	50		75	60	80	60	60	60	50	62	54	50	
25	105	105	80	90	75	60		100	80	100	80	85	80	60	77	65	60	50
35	130	130	100	105	90	80		115	95	120	100	100	95	80	96	77	80	60
50	165	165	150	135	110	100		140	120	150	120	140	130	100	123	104	100	80
70	210	210	200	165	140	120		175	155	200	150	175	165	150	150	125	120	
95	255	250	200	200	170	150		210	190	200		215	200	150	189	166	150	
120	295	195	250	230	200	200	150	245	220	250		245	220	200	228	192	150	
150	340	340	300	270	235	200		290	255	300	250	275	255	200	—	—	—	
185	390	395	300	310	270	250		—	290	300		—	—	—	—	—	—	

Key: (1). Surface work. (2). Separator in tubes. (3). Section, mm². (4). Load, A. (5). Current of insert, A. (6). single-cable. (7). twin-cored. (8). three-strand. (9). two single-cable. (10). three single-cable. (11). two and three single-cable. (12). one twin-cored. (13). one three-strand.

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Table 4-55. the maximum rated currents of the thermal and combined releases of the automatic macnines of series A3100 and the permissible constant lcads fcr the wires and the cables with the aluminum veins/strands (vcltage or up to 1000V), A.

(3) Сечение, мм²	(1) Открытая прокладка											(2) Прокладка в трубах						
	АПР	АНРГ	АПР, АНРГ	АНРГ, АВРГ				ААГ, ААБГ				АПРТО, АНРГ, АВРГ						
	(4) Нагрузка		(5) Номинальный ток расцепителя	(4) Нагрузка		(5) Номинальный ток расцепителя		(4) Нагрузка		(5) Номинальный ток расцепителя		(4) Нагрузка		(5) Номинальный ток расцепителя	(4) Нагрузка		(5) Номинальный ток расцепителя	
	(6) одножильные			(7) двухжильные	(8) трехжильные	(7) двухжильные	(8) трехжильные	(7) двухжильные	(8) трехжильные	(7) двухжильные	(8) трехжильные	(9) два одножильные	(10) три одножильные	(11) два и три одножильные	(12) один двухжильный	(13) один трехжильный	(7) двухжильные	(8) трехжильные
2,5	24	23	25	21	19	20		23	22	25		20	19	20	19	16	20	15
4	32	31	30	29	27	30		31	29	30		28	28	30	25	21	25	20
6	39	38	40	38	32	40	30	42	35	40		36	32	30	31	26	30	25
10	55	60	60	55	42	60	40	55	46	50		50	47	50	42	39	40	
16	80	75	85	70	60	70	60	75	60	85	60	60	60	60	62	54	60	
25	105	105	100	90	75	85		100	80	100	85	85	80	85	77	65	70	
35	130	130	140	105	90	100		115	95	120	100	100	95	100	96	77	85	
50	165	165	170	135	110	120		140	120	140	120	140	130	140	123	104	120	100
70	210	210	200	165	140	140		175	155	170		175	165	170	150	135	140	
95	255	250	250	200	170	200	170	210	190	200		215	200	200	189	166	170	
120	295	195	300	230	200	200		245	220	250		245	200	250	228	192	200	
150	340	340	350	270	235	250		290	255	300		275	255	250	—	—	—	
185	390	395	400	310	270	300		—	290	300		—	—	—	—	—	—	

Key: (1). Surface work. (2). Separator in tubes. (3). Section, mm². (4). Load. (5). Rated current of release. (6). single-cable. (7). twin-cored. (8). three-strand. (9). two single-cable. (10). three single-cable. (11). two and three single-cable. (12). one twin-cored. (13). one three-strand.

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Table 4-56. Permissible loads during intermittent service for the wires and the cables to 1000V with the aluminum veins/strands, laid in the air opened or in the tubes, A.

(3) Номинальное сечение, мм²	(1) Открытая прокладка						(2) Прокладка в трубах													
	АПР, АПВ		АНРГ, АВРГ, АСРГ				АПРТО, АНРГ, АВРГ, АСРГ													
	(4) одножильные		(5) двухжильные		(6) трехжильные		(7) два одножильных		(8) три одножильных		(9) четыре одножильных		(10) один одножильный		(11) один трехжильный					
	ПВ 25%	ПВ 40%	ПВ 25%	ПВ 40%	ПВ 25%	ПВ 40%	ПВ 25%	ПВ 40%	ПВ 25%	ПВ 40%	ПВ 25%	ПВ 40%	ПВ 25%	ПВ 40%	ПВ 25%	ПВ 40%				
2.5	24	24	21	21	19	19	20	20	19	19	19	19	19	19	16	16				
4	32	32	29	29	27	27	28	28	28	28	23	23	25	25	21	21				
6	39	39	38	38	32	32	36	36	32	32	30	30	31	31	26	26				
10	55	55	55	55	42	42	50	50	47	47	39	39	42	42	39	39				
16	140	111	123	97	105	83	105	83	105	83	96	76	108	85	95	75				
25	184	146	158	125	131	103	149	118	140	111	123	97	135	107	114	90				
35	227	179	184	145	157	124	175	138	167	132	149	118	168	133	135	107				
50	289	228	236	186	193	153	245	193	228	180	210	166	215	170	182	144				
70	367	290	289	228	244	193	307	243	289	228	245	193	262	208	236	187				
95	445	352	350	277	297	235	376	298	350	277	307	243	331	262	292	230				
120	515	407	402	318	350	277	428	339	385	304	350	277	400	315	336	265				
150	595	470	473	374	410	324	—	—	—	—	—	—	—	—	—	—				
185	683	540	543	428	472	374	—	—	—	—	—	—	—	—	—	—				

Key: (1). Surface work. (2). Laying in tubes. (3). Nominal section, mm². (4). single-cable. (5). twin-cored. (6). three-strand. (7). two single-cable. (8). three single-cable. (9). four single-cable. (10). one single-cable. (11). one three-strand.

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Section Five

SELECTION OF SECTIONS OF WIRES AND CABLES ON THE PERMISSIBLE LOSS OF VOLTAGE.

5-1. Active and inductive reactances of line.

The effective resistance of wires and cables from the nonferrous metals is determined on one of the following formulas:

$$r = 1000\frac{\rho}{F},\ \text{ом/км}^{(1)},\qquad (5\text{-}1)$$

$$r = \frac{1000}{\gamma F},\ \text{ом/км}^{(1)}.\qquad (5\text{-}2)$$

Key: (1). Ω/km.

where ρ - calculated specific resistor/resistance of wire or cable core, Ω•mm²/m;

γ - calculated specific conductivity of wire or cable core, m/Ω•mm²;

F - nominal section of wire or cable, mm².

Values of specific resistor/resistance and specific conductivity

for copper wires and cables:

$$\rho_{м}=0{,}0189\ ом^{(1)}\cdot мм^2/м;\ \gamma_{м}=53\ м/ом^{(2)}\cdot мм^2;$$

Key: (1). $\Omega \bullet mm^2/m$. (2). $m/\Omega \bullet mm^2$;

for aluminum wires and cables

$$\rho_{а}=0{,}0315\ ом^{(1)}\cdot мм^2/м;\ \gamma_{а}=31{,}7\ м/ом^{(2)}\cdot мм^2.$$

Key: (1). $\Omega \bullet mm^2/m$. (2). $m/\Omega \bullet mm^2$.

Table 5-1. The effective resistance of wires and cables, Ω/km.

(1) Сечение провода, мм²	(2) Медные провода и кабели	(3) Алюминиевые провода и кабели	(4) Сталеалюминиевые провода
1	18,9	—	—
1,5	12,6	—	—
2,5	7,55	12,6	—
4	4,65	7,90	—
6	3,06	5,26	—
10	1,84	3,16	3,12
16	1,20	1,98	2,06
25	0,74	1,28	1,38
35	0,54	0,92	0,85
50	0,39	0,64	0,65
70	0,28	0,46	0,46
95	0,20	0,34	0,33
120	0,158	0,27	0,27
150	0,123	0,21	0,21
185	0,103	0,17	0,17
240	0,078	0,132	0,132
300	0,062	0,106	0,107
400	0,047	0,08	0,08

Key: (1). Section of wire, mm². (2). Copper wires and cables. (3). Aluminum wires and cables. (4). Steel-aluminum wires.

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Table 5-2. Inductive reactances of aerial lines, Ω/km.

(1) Среднее геометрическое расстояние между проводами, мм	(2) Сечение проводов, мм²										
	6	10	16	25	35	50	70	95	120	150	185
	(3) Индуктивное сопротивление										
	(4) Медные провода										
400	0,371	0,355	0,333	0,319	0,308	0,297	0,283	0,274	—	—	—
600	0,397	0,381	0,358	0,345	0,336	0,325	0,309	0,300	0,292	0,287	0,280
800	0,415	0,399	0,377	0,363	0,352	0,341	0,327	0,318	0,310	0,305	0,298
1 000	0,429	0,413	0,391	0,377	0,366	0,355	0,341	0,332	0,324	0,319	0,313
1 250	0,443	0,427	0,405	0,391	0,380	0,369	0,355	0,346	0,338	0,333	0,327
1 500	—	0,438	0,416	0,402	0,391	0,380	0,366	0,357	0,349	0,344	0,338
2 000	—	0,457	0,435	0,421	0,410	0,398	0,385	0,376	0,368	0,363	0,357
2 500	—	—	0,449	0,435	0,424	0,413	0,399	0,390	0,392	0,377	0,371
3 000	—	—	0,460	0,446	0,435	0,423	0,410	0,401	0,393	0,388	0.382
	(5) Алюминиевые провода										
600	—	—	0,358	0,345	0,336	0,325	0,315	0,303	0,297	0,288	0,279
800	—	—	0,377	0,363	0,352	0,341	0,331	0,319	0,313	0,305	0,298
1 000	—	—	0,391	0,377	0,366	0,355	0,345	0,334	0,327	0,319	0,311
1 250	—	—	0,405	0,391	0,380	0,369	0,359	0,347	0,341	0,333	0,328
1 500	—	—	—	0,402	0,391	0,380	0,370	0,358	0,352	0,344	0,339
2 000	—	—	—	0,421	0,410	0,398	0,388	0,377	0,371	0,363	0,355
	(6) Сталеалюминиевые провода										
2 000	—	—	—	—	0,403	0,392	0,382	0,371	0,365	0,358	—
2 500	—	—	—	—	0,417	0,406	0,396	0,385	0,379	0.272	—
3 000	—	—	—	—	0,429	0,418	0,408	0,397	0,391	0,384	0.377

Key: (1). Geometrical mean separation, mm. (2). Section of wires, mm². (3). Inductive reactance. (4). Copper wires. (5). Alumirum wires. (6). Steel-alumirum wires.

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Table 5-3. Active and internal inductive reactances of aerial lines, made by steel wires, Ω/км.

Ток (1) линии, а	(2) Активное сопротивление							(3) Внутреннее индуктивное сопротивление						
	ПСО-3.5	ПСО-4	ПСО-5	ПС-25	ПС-35	ПС-50	ПС-70	ПСО-3.5	ПСО-4	ПСО-5	ПС-25	ПС-35	ПС-50	ПС-70
0,5	14,9	11,5	—	—	—	—	—	1,04	0,69	—	—	—	—	—
1	15,2	11,8	—	5,25	3.66	2,75	1,70	2,27	1,54	—	0,54	0,33	0,23	0,16
1,5	15,7	12,3	7,9	5,26	3,66	2,75	1,70	4,24	2,82	2,13	0,55	0,34	0,23	0,16
2	16,1	12,5	8,35	5,27	3,66	2,75	1,70	6,45	4,38	3,58	0,55	0,35	0,24	0,17
3	17,4	13,4	9,5	5,28	3,67	2,75	1,70	9,60	7,90	6,45	0,56	0,36	0,25	0,17
4	18,5	14,3	10,8	5,30	3,69	2,75	1,70	11,9	9,70	8,10	0,59	0,37	0,25	0,18
5	20,1	15,5	12,3	5,32	3,70	2,75	1,70	14,1	11,5	9,7	0,63	0,40	0,26	0,18
6	21,4	16,5	13,8	5,35	3,71	2,75	1,70	16,3	12,5	11,2	0,67	0,42	0,27	0,19
7	21,5	17,3	15,0	5,37	3,73	2,75	1,70	16,5	13,2	12,3	0,70	0,45	0,27	0,19
8	21,7	18,0	15,4	5,40	3,75	2,76	1,70	16,7	14,2	13,3	0,77	0,48	0,28	0,20
9	21,8	18,1	15,2	5,45	3,77	2,77	1,70	16,9	14,3	13,1	0,84	0,51	0,29	0,20
10	21,9	18,1	14,6	5,50	3,80	2,78	1,70	17,1	14,3	12,4	0,93	0,55	0,30	0,21
15	20,2	17,3	13,6	5,97	4,02	2,80	1,70	18,3	13,3	11,4	1,33	0,75	0,35	0,23
20	—	—	12,7	6,70	4,40	2,85	1,72	—	—	10,5	1,63	1,04	0,42	0,25
25	—	—	—	6,97	4,89	2,95	1,74	—	—	—	1,91	1,32	0,49	0,27
30	—	—	—	7,10	5,21	3,10	1,77	—	—	—	2,01	1,56	0,59	0,30
35	—	—	—	7,10	5,36	3,25	1,79	—	—	—	2,06	1,66	0,69	0,33
40	—	—	—	7,02	5,35	3,40	1,83	—	—	—	2,09	1,69	0,80	0,37
45	—	—	—	6,92	5,30	3,52	1,88	—	—	—	2,08	1,71	0,91	0,41
50	—	—	—	6,85	5,25	3,61	1,93	—	—	—	2,07	1,72	1,00	0,45
60	—	—	—	6,70	5,13	3,69	2,07	—	—	—	2,00	1,70	1,10	0,55
70	—	—	—	—	5,00	3,73	2,21	—	—	—	—	1,64	1,14	0,65
80	—	—	—	—	—	3,70	2,27	—	—	—	—	—	1,15	0,70
90	—	—	—	—	—	3,68	2,29	—	—	—	—	—	1,14	0,72
100	—	—	—	—	—	—	2,33	—	—	—	—	—	—	0,73
125	—	—	—	—	—	—	2,33	—	—	—	—	—	—	0,73

Key: (1). That line, A. (2). Effective resistance. (3). Internal inductive reactance.

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Table 5-4. Inductive reactances of triple-cores cable and insulated wires, laid on the rollers and insulators, Ω/km.

(1) Сечение, мм²	(2) Трехжильные кабели с медными жилами				(3) Изолированные провода	
	(4) до 1 (5) кв	3 (5) кв	6 (5) кв	10 (5) кв	(6) на роликах	(7) на изоляторах
1,5	—	—	—	—	0,28	0,32
2,5	—	—	—	—	0,26	0,30
4	0,095	0,111	—	—	0,25	0,29
6	0,090	0,104	—	—	0,23	0,28
10	0,073	0,0825	0,11	0,122	0,22	0,26
16	0,0675	0,0757	0,102	0,113	0,22	0,24
25	0,0662	0,0714	0,091	0,099	0,20	0,24
35	0,0637	0,0688	0,087	0,095	0,19	0,24
50	0,0625	0,0670	0,083	0,09	0,19	0,23
70	0,0612	0,0650	0,08	0,086	0,19	0,23
95	0,0602	0,0636	0,078	0,083	0,18	0,23
120	0,0602	0,0626	0,076	0,081	0,18	0,22
150	0,0596	0,0610	0,074	0,079	—	—
185	0,0596	0,0605	0,073	0,077	—	—
240	0,0587	0,0595	0,071	0,075	—	—

Key: (1). Section, mm². (2). Triple-cores cable with copper veins/strands. (3). Insulated wires. (4). to. (5). kV. (6). on rollers. (7). on insulators.

Table 5-5. External inductive reactances of aerial lines with the steel wires.

(1) Среднее геометрическое расстояние между проводами, мм	(2) Марка проводов						
	ПСО-3,5	ПСО-4	ПСО-5	ПС-25	ПС-35	ПС-50	ПС-70
	(3) Внешнее индуктивное сопротивление x', ом/км						
400	0,341	0,332	0,318	0,311	0,290	0,281	—
600	0,368	0,359	0,345	0,336	0,317	0,308	0,295
800	0,384	0,375	0,361	0,354	0,333	0,324	0,311
1 000	0,398	0,389	0,375	0,368	0,347	0,338	0,325
1 250	—	0,403	0,489	0,381	0,361	0,352	0,339
1 500	—	0,414	0,400	0,393	0,372	0,363	0,350
2 000	—	—	—	0,412	0,391	0,382	0,369

Key: (1). Geometrical mean separation, mm. (2). Brand of wires. (3). External inductive reactance x', Ω/km.

Table 5-6. Active (ohmic) and inductive reactances of the busbars of rectangular cross section from aluminum and copper.

(1) Размеры шин, мм	(2) Активное (омическое) сопротивление при температуре шины +30° С, ом/км				(3) Индуктивное сопротивление при расстоянии между центрами шин 250 мм, ом/км
	(4) Алюминиевые шины		(5) Медные шины		
	(6) при постоянном токе	(7) при переменном токе	(6) при постоянном токе	(7) при переменном токе	
25×3	0,410	0,418	0,248	0,263	0,253
30×4	0,256	0,269	0,156	0,175	0,240
40×4	0,192	0,211	0,117	0,138	0,224
40×5	0,154	0,173	0,0935	0,112	0,222
50×5	0,123	0,140	0,0749	0,0913	0,210
50×6	0,102	0,119	0,0624	0,0780	0,208
60×6	0,0855	0,102	0,0520	0,0671	0,198
80×6	0,0640	0,0772	0,0390	0,0507	0,182
100×6	0,0510	0,0635	0,0312	0,0411	0,169
60×8	0,0640	0,0772	0,0390	0,0507	0,196
80×8	0,0481	0,0595	0,0293	0,0395	0,179
100×8	0,0385	0,0488	0,0234	0,0321	0,168
120×8	0,0320	0,0410	0,0195	0,0271	0,156
80×10	0,0385	0,0495	0,0234	0,0323	0,179
100×10	0,0308	0,0398	0,0187	0,0260	0,165
120×10	0,0255	0,0331	0,0156	0,0218	0,156

Key: (1). Sizes/dimensions of busbars, mm. (2). Active (ohmic) resistor/resistance at temperature of busbar of +30°C, Ω/km. (3). Inductive reactance with distance between centers of busbars 250 mm, Ω/km. (4). Aluminum busbars. (5). Copper busbars. (6). with direct current. (7). with alternating current.

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Table 5-7. Active and inductive resistors/resistances of conductors with the aluminum busbars of series ShMA and ShRA.

(1) Тип	(2) Сопротивление, ом/км	
	(3) активное	(4) индуктивное
(5) Магистральные токопроводы		
ШМА59-1	0,024	0,02
ШМА59-2	0,016	0,02
ШМА59-4	0,010	0,02
(6) Распределительные токопроводы		
ШРА60-2	0,21	0,18
ШРА60-4	0,13	0,16
ШРА60-6	0,08	0,11

Key: (1). Type. (2). Resistor/resistance, Ω/km. (3). active. (4). inductive. (5). Main-line conductors. (6). Distributive conductors.

Table 5-8. Maximum values oi the sections of wires and cables for which to admissibly conduct calculation on the loss of voltage without taking into account inductive reactance of wires (for the net of alternating current with the frequency of 50 Hz).

(1) Коэффициент мощности	0.95		0.9		0.85		0.8		0.75		0.7	
(2) Материал проводов	М	А	М	А	М	А	М	А	М	А	М	А
(3) Кабели до 1 *кв*	70	120	50	95	35	70	35	50	25	50	25	35
(4) Кабели 6—10 *кв*	50	95	35	50	25	50	25	35	16	25	16	25
(5) Провода в трубах	50	95	35	50	35	50	25	35	16	25	16	25
(6) Провода на роликах	25	35	16	25	10	16	10	10	6	10	6	10
(7) Провода на изоляторах	16	25	10	16	10	16	6	10	6	10	6	6

Note. M- copper wires and cables; A - aluminum wires and cables.

Key: (1). Power factor. (2). Material of wires. (3). Cables to 1 kV. (4). Cables 6-10 kV. (5). Wires in tubes. (6). Wires on rollers. (7). Wires on insulators.

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Table 5-9. Values and units are the measurement of the values, entering formulas (5-6) and (5-7).

(1) Система тока	(2) Сумма моментов нагрузок по участкам линий: M_a	(3) Единицы измерения	(4) Потеря напряжения ΔU	(5) Значение коэффициента c_1	(6) Числовое значение коэффициента c_2 для алюминиевых (числитель) и медных (знаменатель) проводов и кабелей при номинальном междуфазном напряжении, кв: 0,22	0,38	0,66	6	10
(7) Однофазный переменный или постоянный ток	$\Sigma I_a l$	(8) а·м	(9) в	$\frac{2}{\gamma}$	$\frac{0,0631}{0,0377}$				
			%	$\frac{2}{10\gamma U_н}$	$\frac{0,0287}{0,0171}$	$\frac{0,0166}{0,00992}$	$\frac{0,00956}{0,00571}$	—	—
	ΣPl	(10) квт·м	(9) в	$\frac{2}{\gamma U_н}$	$\frac{0,287}{0,171}$	$\frac{0,166}{0,0992}$	$\frac{0,0957}{0,0571}$	—	—
			%	$\frac{2}{10\gamma U_н^2}$	$\frac{0,130}{0,0777}$	$\frac{0,0437}{0,0261}$	$\frac{0,0145}{0,00865}$	—	—
(11) Трехфазный переменный ток	$\Sigma I_a l$	(8) а·м	(9) в	$\frac{\sqrt{3}}{\gamma}$	$\frac{0,0545}{0,0326}$				
			%	$\frac{\sqrt{3}}{10\gamma U_н}$	$\frac{0,0248}{0,0148}$	$\frac{0,0143}{0,00858}$	$\frac{0,00826}{0,00494}$	—	—
	ΣPl	(10) квт·м	(9) в	$\frac{1}{\gamma U_н}$	$\frac{0,143}{0,0855}$	$\frac{0,083}{0,0496}$	$\frac{0,0478}{0,0286}$	—	—
			%	$\frac{1}{10\gamma U_н^2}$	$\frac{0,0653}{0,0389}$	$\frac{0,0219}{0,0131}$	$\frac{0,00725}{0,00433}$	—	—
(11) Трехфазный переменный ток	ΣPl	(12) квт·км	(9) в	$\frac{1\,000}{\gamma U_н}$	$\frac{143,0}{85,5}$	$\frac{83,0}{49,6}$	$\frac{47,8}{28,6}$	$\frac{5,25}{3,14}$	$\frac{3,16}{1,89}$
			%	$\frac{100}{\gamma U_н^2}$	$\frac{65,3}{38,9}$	$\frac{21,9}{13,1}$	$\frac{7,25}{4,33}$	$\frac{0,0875}{0,0523}$	$\frac{0,0316}{0,0189}$
		(13) Мвт·км	(9) в	$\frac{10^6}{\gamma U_н}$	—	—	—	$\frac{5\,250}{3\,140}$	$\frac{3\,160}{1\,890}$
			%	$\frac{10^5}{\gamma U_н^2}$	—	—	—	$\frac{87,5}{52,3}$	$\frac{31,6}{18,9}$
(14) Ответвления от четырехпроводной линии трехфазного тока: (15) а) однофазное	ΣPl	(10) квт·м	%	$\frac{6}{10\gamma U_н^2}$	$\frac{0,392}{0,233}$	$\frac{0,131}{0,0786}$	—	—	—
(16) б) двухфазное			%	$\frac{2,25}{10\gamma U_н^2}$	$\frac{0,147}{0,0875}$	$\frac{0,0493}{0,0295}$	—	—	—

Note. In the given formulas are accepted the following general/common/total units the measurement: specific conductivity γ, m/Ω•mm² nominal interphase voltage U_n, kV.

Key: (1). System of current. (2). Sum of load moments on sections of lines. (3). Units measurement. (4). Loss of voltage. (5). Value of coefficient. (6). Numerical value of coefficient α_1 for aluminum (numerator) and copper (denominator) wires and cables with nominal interphase voltage, kV. (7). Single-phase alternating or direct current. (8). A•m. (9). in. (10). kW•m. (11). Three-phase alternating current. (12). kW•km. (13). MW•km. (14). Branchings from four-wire line of three-phase current. (15). single-phase. (16). two-phase.

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Inductive reactance of three-phase line with the wires from the nonferrous metals at the frequency of alterrating current 50 Hz is determined from the formula

$$x = 0{,}1145 \lg \frac{2D}{d} + 0{,}016, \quad \Omega/km, \quad (5\text{-}3)$$

where d - outer diameter of wire, mm;

D - geometrical mean separation of line, computed from the formula

$$D=\sqrt[3]{D_{12}D_{23}D_{31}},\ \text{мм}. \quad (5\text{-}4)$$

In (5-4) D_{12}, D_{23} and D_{31} - separation in each pair of the wires of three-phase line, mm.

Effective resistance to 1 km of wire or cable core are given to Table 5-1, inductive resistors/resistances to 1 km of line - in Table 5-2 and 5-4.

For the steel wires active and internal inductive the resistors/resistances depend on the taking place on the wire alternating current and are determined in depending on current on Table 5-3. External inductive reactances of aerial lines, made by steel wires, are given in Table 5-5. General/common/total inductive reactance of aerial line, made by steel wires, is defined as sum external x' and internal x" inductive reactances:

$$x=x'+x'',\ \Omega/\text{km}. \quad (5\text{-}5)$$

Active and inductive the resistor/resistance of conductor, made from aluminum or copper busbars, are given in Table 5-6. Effective resistance exceeds ohmic due to the surface/skin effect.

For the conductors of series ShRA and ShM (article of the

plants of Glavelektromcntazh [- Main Administration for Installaticn cf Electrical Equipment cf Electric Power Plants and Substations]) the values of resistcrs/resistances are given in Table 5-7.

5-2. Calculation of network/grid according to the permissible loss of voltage without taking into account inductive reactance of line.

Without taking into account inductive reactance of line for the loss of voltage they are designed:

1) mains of the direct current;

2) the line of the net of alternating current, for which the power factor is equal to 1 ($\cos\phi = 1$);

3) the nets, made by wires within the buildings or cables, if their sections do not exceed the indicated in Table 5-8 values.

With the assigned section of the wires of loss contour of voltage is determined from the formula

$$\Delta U = e_1 \frac{M_a}{F}. \quad (5\text{-}6).$$

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Section with the assigned loss of voltage is calculated from the formula

$$F = a_1 \frac{M_a}{\Delta U}, \text{ мм}^2. \quad (5\text{-}7)$$

where F - a section of wire, mm^2; ΔU - loss of voltage in the line, V or o/o; M_a - sum of the load moments, i.e., the sum of the products of the resistive loads, transmitted by the sections of line, on the lengths of these sections; a_1 - coefficient, depending on the system of current and accepted during the computations units measurement for the entering the formula values.

Values and units the measurement of the values, entering in (5-6) and (5-7), are given in Table 5-9.

Example 5-1. Fig. 5-1 gives network of air four-wire net 380/220 V. The lengths of the sections of net are shown in the diagram in the kilometers, loads - in the kilowatts, factor of power cos ϕ=1. To produce the calculation of net to the loss of voltage, if the permissible loss of voltage ΔU=4o/o. Material of the wires of net

- aluminum.

Solution. Calculation is produced according to formulas (5-6) and (5-7). We find their Tables 5-9 of value of coefficient a_1 for the loads, expressed in the kilowatts, the lengths of the sections of line in the kilometers and the loss of voltage in the percentages. Under these conditions we will obtain:

$$a_1 = \frac{100}{\gamma U_н^2}.$$

In our case nominal interphase line voltage $U_н = 0.38$ kV; the specific conductivity of aluminum $\gamma = 31.7$ m/Ω•mm², whence the numerical value of the coefficient

$$a_1 = \frac{100}{31.7 \cdot 0.38^2} = 21.9 \ \Omega \cdot mm^2/m \cdot kV^2.$$

The numerical value of coefficient a_1 can be directly obtained from Table 5-9.

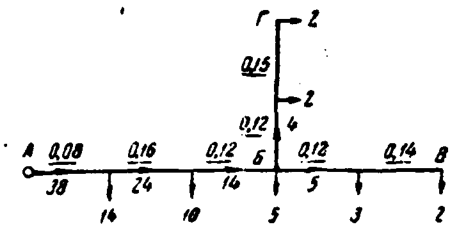

Fig. 5-1. Diagram for example 5-1.

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We determine values M_a for the fundamental main line and the branchings:

$$M_{aAB} = 38\cdot 0,08 + 24\cdot 0,16 + 14\cdot 0,12 = 8,56 \text{ квт}\cdot\text{км}; (1)$$
$$M_{aБВ} = 5\cdot 0,12 + 2\cdot 0,14 = 0,88 \text{ квт}\cdot\text{км}; (1)$$
$$M_{aБГ} = 4\cdot 0,12 + 2\cdot 0,15 = 0,78 \text{ квт}\cdot\text{км}. (1)$$

Key: (1) kW•km.

Great value M_a is obtained in the section ABV:

$$M_{a.макс} = 8,56 + 0,88 = 9,44 \text{ kW•km}.$$

After substituting numerical values in (5-7), let us determine the minimally permissible section of line according to the condition of the galleries of the voltage:

$$F = a_1 \frac{M_a}{\Delta U} = 21,9\cdot\frac{9,44}{4} = 51,5 \text{ мм}^2.$$

We accept the section of phase conductors for the main line AB

equal to:

$$F_{AB}=70\ мм^2.$$

The section of neutral conductor we take as for the main line the equal to the half the phase:

$$F_{0AB}=35\ мм^2.$$

We find the loss of voltage in the main line AB through (5-6):

$$\Delta U_{AB}=e_1\frac{M_{aAB}}{F_{AB}}=21,9\cdot\frac{8,56}{70}=2,68\%.$$

Loss of voltage, permitted for the tranchings BV and BG,

$$\Delta U_{B}=4-2,68=1,32\%.$$

We determine the section of tranching BV:

$$F_{BB}=21,9\cdot\frac{0,88}{1,32}=14,6\ мм^2$$

and the section of branching BG:

$$F_{BГ}=21,9\cdot\frac{0,78}{1,32}=12,9\ мм^2.$$

According to the condition of the mechanical strength (see Table 1-11) we accept the sections of phase and neutral conductors for the tranchings BV and BG equal to 16 mm².

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5-3. Calculation of net according to loss of voltage taking into account inductance of lines.

The losses of voltage with the assigned section of the wires of line taking into account inductive reactance of line with different

coefficients cf power lcading cf line it is determined from the formula

$$\Delta U = \alpha_2 (rM_a + xM_r); \quad (5\text{-}8)$$

with the identical power factor for all loads of the line

$$\Delta U = \alpha_2 (r\cos\varphi + x\sin\varphi) M, \quad (5\text{-}9)$$

where ΔU - a loss of voltage in the line, V or o/o; r and x - active and inductive reactances or line, Ω/km; M_a - sum of the moments/torques of the resistive loads; M_r - sum of the moments/torques of the reactive load; M - sum of the moments/torques of the full loads; α_2 - coefficient, depending on the system of the current and the units accepted measurement for the entering the formulas values.

Values α_2 and units the measurement of the values, entering in (5-8) and (5-9), are given in Table 5-12.

The selection of the section of the wires of line in the assigned magnitude of losses of voltage taking into account the inductance of line is conducted as follows.

Table 5-10. The standard deviaticns of vcltage from the nominal on the terminals/grippers cf electrical receivers with respect tc GOST 13109-67.

(1) Наименования электроприемников	(2) Допустимые пределы отклонений напряжения на зажимах электроприемников от номинального, %
(3) Электродвигатели	(6) +10 и −5
(4) Лампы рабочего освещения промышленных предприятий и общественных зданий, лампы прожекторных установок наружного освещения	+5 и −2,5
(5) Остальные электроприемники	+5 и −5

Note. In the after-emergency modes/conditicns is allowed/assumed supplementary decrease in the vcltage on 5o/c.

Key: (1). Designations cf electrical receivers. (2). Permissitle limits of deviation cf lcad vcltage of electrical receivers from nominal, o/o. (3). Electric mctcrs. (4). Tubes cf working illumination of industrial enterprises and putlic buildings, lamp cf searchlight installaticns of exterior lighting. (5). Remaining electrical receivers. (6) and.

Table 5-11. Oscillations/vitrations of voltage, permitted on the terminals/grippers of tubes and radio sets cn GCST 13109-67.

(1) Число колебаний напряжения в час	(2) Допустимые величины колебания напряжения от номинального, %
2	4
4	2,5
6	2
8	1,75
10	1,6
15	1,4
20	1,3
30	1,2
50	1,12
100	1,06
>100	1,0

Key: (1). Number of oscillations/vibrations of voltage in the hour. (2). Permissible values of oscillation/vibration of voltage from nominal, o/o.

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Is determined the value of the calculated value of the loss of voltage according to the formula

$$\Delta U_a = \Delta U - a_2 x_{cp} M_r, \quad (5\text{-}10)$$

where ΔU - the permissible loss of voltage in the line, V or o/c; M_r - maximum value of the sum of the moments/torques of reactive load for the designed line; x_{cp} - average/mean inductive reactance of line, Ω/km.

The values of average/mean inductive reactances of line are given in Table 5-13.

Subsequently the calculation is conducted on (5-6) and (5-7).

According to the termination of calculation the magnitude of losses of voltage in the line is more precisely formulated on (5-8) or (5-9).

Example 5-2. Fig. 5-2 gives network of air three-phase line 6 kV. Resistive loads in the megawatts in the diagram are shown in the numerators of fractions, reactive load in the mega-pitches/mega-vars - in their denominators, the lengths of lines - in the kilometers. Power factor for all loads of net is identical and equal to 0.85. To produce the calculation of line to the loss of voltage taking into account the inductance of wires. Material of wires - aluminum. Medium separation $\overline{D}_{ср}=1250$ mm. Permissible loss of voltage ΔU=6.5o/c.

Solution. We determine the moments/torques of the active and reactive load of the sections of the line:

(1) Обозначения участка линии	(2) $M_а$, Мвт·км	(3) $M_р$, Мвар·км
АБ	0,983·2=1,97	0,611·2=1,222
БВ	0,085·9=0,765	0,053·9=0,477
БГ	0,27·4=1,08	0,168·4=0,672
БД	0,153·6=0,92	0,095·6=0,57

Key: (1). Designations of the section of line. (2). MW•km. (3). Mvar•km.

From Table 5-12

$$a_s = 2{,}78 \ 1/kV^2.$$

From Table 5-13

$$x_{ep} = 0{,}4 \ \Omega/km.$$

Maximum value M_r (fcr the section of line ABG)

$$M_{r\,AB\Gamma} = 1{,}222 + 0{,}672 = 1{,}894 \text{ Mvar}\cdot\text{km}.$$

We determine the calculated value of the loss of voltage on (5-10):

$$\Delta U_a = 6{,}5 - 2{,}78 \cdot 0{,}4 \cdot 1{,}894 = 4{,}4\%.$$

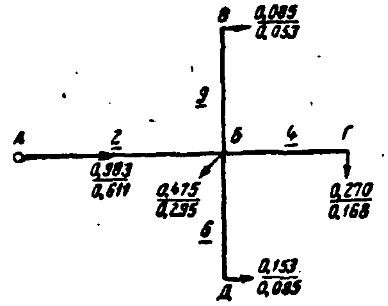

Fig. 5-2. Diagram for example 5-2.

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We determine the section of wire on (5-7). Value of coefficient α_1 in tables 5-9

$$\alpha_1 = 87{,}5 \ \Omega\cdot mm^2/m\cdot kV^2.$$

Maximum value M_a (for the section of line ABG)

$$M_a = 1{,}97 + 1{,}08 = 3{,}05 \ MW\cdot km.$$

Minimum section of the line

$$F = 87{,}5 \cdot \frac{3{,}05}{4{,}4} = 60{,}7 \ mm^2.$$

We accept the section of main line AB the equal to 70 mm^2.

We determine the loss of voltage in the section AB on (5-6):

$$\Delta U_{aAB} = 87{,}5 \cdot \frac{1{,}97}{70} = 2{,}46 \%.$$

Table 5-12. Values and units are the measurement of the values, entering formulas (5-8) and (5-9).

(1) Системы тока	(2) Сумма моментов нагрузок по участкам линий						(6) Потери напряжения	(7) Значение коэффициента α_2	(8) Числовое значение коэффициента α_2 при номинальном междуфазном напряжении, кв				
	(3) активных		(4) реактивных		(5) полных								
	M_a	(9) единица измерения	M_r	(9) единица измерения	M	(9) единица измерения			0,22	0,38	0,66	6	10
(10) Однофазный переменный ток	$\Sigma I_a l$	$a \cdot км$	$\Sigma I_r l$	$a \cdot км$	ΣIl	$a \cdot км$	в	2	2				
							%	$\frac{2}{10U_н}$	0,909	0,526	0,303	0,0333	0,02
	ΣPl	(11) $квт \cdot км$	ΣQl	(12) $квар \cdot км$	ΣSl	(13) $ква \cdot км$	в	$\frac{2}{U_н}$	9,09	5,26	3,03	0,333	0,2
							%	$\frac{2}{10U_н^2}$	4,13	1,38	0,459	0,00555	0,002
(14) Трехфазный переменный ток	$\Sigma I_a l$	$a \cdot км$	$\Sigma I_r l$	$a \cdot км$	ΣIl	$a \cdot км$	в	$\sqrt{3}$	1,73				
							%	$\frac{\sqrt{3}}{10U_н}$	0,787	0,455	0,263	0,0289	0,0173
	ΣPl	(11) $квт \cdot км$	ΣQl	(12) $квар \cdot км$	ΣSl	(13) $ква \cdot км$	в	$\frac{1}{U_н}$	4,55	2,63	1,52	0,167	0,1
							%	$\frac{1}{10U_н^2}$	2,07	0,69	0,23	0,00278	0,001
	ΣPl	(14) $Мвт \cdot км$	ΣQl	(15) $Мвар \cdot км$	ΣSl	(16) $Мва \cdot км$	в	$\frac{1\,000}{U_н}$	—	—	—	167	100
							%	$\frac{100}{U_н^2}$	—	—	—	2,78	1

Key: (1). Systems of current. (2). Sum of load moments on sections of lines. (3) active. (4) reactive/jet. (5) complete. (6). Losses of voltage. (7). Value of coefficient. (8). Numerical value of coefficient α_2 with nominal interphase voltage, kV. (9) unit measurement. (10). Single-phase alternating current. (11) kW•km. (12) kvar•km. (13) kVA•km. (14). Three-phase alternating current. (15). Mvar•km. (16). MVA•km.

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Loss of voltage, permitted for the tranchings from the point B of the line

$$\Delta U_{aB} = 4.4 - 2.46 = 1.94\%.$$

We determine the sections of the wires of the branchings:

$$F_{БВ} = 87,5 \cdot \frac{0,765}{1,94} = 34,5\ мм^2$$ (принимаем провод A35);

$$F_{БГ} = 87,5 \cdot \frac{1,08}{1,94} = 48,3\ мм^2$$ (принимаем провод A50);

$$F_{БД} = 87,5 \cdot \frac{0,82}{1,94} = 41,5\ мм^2$$ (принимаем (1) провод A50).

Key: (1) is taken wire.

We find values of active and inductive reactances from Tabl. 5-1 and 5-2 and more precisely formulate the values of the losses of voltage of up to the points V, G and D of line on (5-8):

$$\Delta U_{АБВ} = 2,78\,[(0,46 \cdot 1,97 + 0,359 \cdot 1,222) + (0,92 \cdot 0,765 + 0,38 \cdot 0,477)] = 6,20\ \%;$$
$$\Delta U_{АБГ} = 6,36\ \% \text{ и } \Delta U_{АБД} = 5,96\ \%.$$

Verifying calculation shows that all sections accepted satisfy the condition of problem.

Table 5-13.

(1) Характеристика сети	(2) Средние значения индуктивных сопротивлений, ом/км
(3) Кабель до 1 кв	0,06
(4) Кабель 6—10 кв	0,08
(5) Изолированные провода на роликах	0,2
(6) Изолированные провода на изоляторах	0,25
(7) Воздушные линии до 1 кв	0,3
(8) Воздушные линии 6—10 кв	0,4

Key: (1). Characteristic of net. (2). Average/mean values of inductive reactances, Ω/km. (3). Cable to 1 kV. (4). Cable 6-10 kV. (5). Insulated wires on rollers. (6). Insulated wires on insulators. (7). Aerial lines to 1 kV. (8). Aerial lines 6-10 kV.

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5-4. Calculation according to loss of voltage of line of alternating current, performed by steel wires.

The determination of the loss of voltage in the line, made by steel wires, is conducted according to the formulas: the three-phase line

$$\Delta U = \sqrt{3}\,[r\cos\varphi + (x' + x'')\sin\varphi]\,Il; \qquad (5\text{-}11)$$

the single-phase line

$$\Delta U = 2[r\cos\varphi + (x' + x'')\sin\varphi]\,Il, \qquad (5\text{-}12)$$

where r - effective resistance of steel wire, determined in depending

on the current of line on Tables 5-3, Ω/km; x' - external inductive reactance of line, determined in depending on the separation on Tables 5-5, Ω/km; x" - internal inductive reactance of steel wire, determined in depending on the current of line on Tables 5-3, Ω/km; cos ϕ - coefficient of power loading of the line; I - load of line, A; l - length of line, km.

During the determination of section the lines from the loss of voltage are assigned by the section of steel wire and is checked the section accepted to the loss of voltage on (5-11) or (5-12).

Example 5-3. Air three-phase line to the voltage 6 kV with a length of 2.5 km is made by steel wires. Load of line I=15 a with the factor of power cos ϕ=0.8. Medium separation of line 1000 mm. Permissible loss of voltage ΔU=6.5o/o. To determine the section of wires.

Solution. We check the possibility of the execution of line by steel wires of model PSO-5.

From Table 5-3 we find for the current of line 15 and the value of the active and internal inductive of the resistors/resistances of the wire of model PSO-5:

r=13.6 Ω/km; x" =11.4 Ω/km,

while from table 5-5 - a value cf external inductive reactance with D=1 000 mm:

x'=0.375 Ω/km.

According to the conditicns of the problem

$$I=15\ a;\ l=2{,}5\ км;\ \cos\varphi=0{,}8;\ \sin\varphi=0{,}6.$$

On (5-11) we determine the loss of voltage in the line with the fulfillment by its wires of model PSO-5:

$$\Delta U=\sqrt{3}\,[13{,}6\cdot 0{,}8+(0{,}375+11{,}4)\cdot 0{,}6]\cdot 15\cdot 2{,}5=$$

=1 160 V, or 1 160/6 000•100=19.4o/o, which is inadmissible.

We check analogously the possibility of the execution of line by the steel stranded wires of model PS-25. For these wires the loss of voltage in the line comprises:

$$\Delta U=\sqrt{3}\,[5{,}97\cdot 0{,}8+(0{,}368+1{,}33)\cdot 0{,}6]\cdot 15\cdot 2{,}5=$$
$$=378\ V,\ \text{or}\ \frac{378\cdot 100}{6\,000}=6{,}3\,\%,$$

which satisfies the condition presented.

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5-5. Calculation of net with the aid of auxiliary tables of specific losses of voltage.

Table 5-14-5-28 gives the specific losses of voltage for the electric wirings, the air and cable lines and the conductors in the dependence on the value of power factor. For the wires and the cables from the nonferrous metal these losses are expressed in the percentages to 1 kW•m, kW•km or MW•km in depending on the voltage of line.

For the lines, made by steel wires, the specific losses of voltage are shown in the volts on 1 km of line.

The loss of voltage in the line with the assigned section of wires and cables from the nonferrous metals is determined from the formula

$$\Delta U = \Delta U_{\text{т6}} M_{a}, \qquad (5\text{-}13)$$

where M_a - sum of the products of resistive loads on the lengths of the sections of line (kW•m, kW•km, MW•km); $\Delta U_{\text{т6}}$ - tabular value of the specific magnitude of losses of voltage in the percentages on 1 kW•m, kW•km or MW•km.

The determination of the section of wires from the assigned magnitude of losses of voltage is conducted as follows. Is determined

computed value $\Delta U_{\tau 6}$ according to the formula

$$\Delta U_{\tau 6} < \frac{\Delta U}{M_a} \tag{5-14}$$

and on the appropriate table is selected the section of wire with the nearest smaller value of the specific loss of voltage.

The loss of voltage in the line for the steel wires is determined from the formula

$$\Delta U = \Delta U_{\tau 6} l, \tag{5-15}$$

where l - length of line, km; $\Delta \bar{U}_{\tau 6}$ - tabular value of the specific loss of voltage, V/km.

Computed value of the specific loss of voltage during the determination of the section of wires from the assigned permissible magnitude of losses of voltage is calculated from the formula

$$\Delta U_{\tau 6} < \frac{\Delta U}{l}. \tag{5-16}$$

The specific values of the losses of voltage for the conductors with the steel busbars in the percentages or 1 A•km are given in Table 5-27. For the intermediate values of the current of line the magnitude of losses of voltage is determined by interpolation according to the formula

$$\Delta U_{\tau 6} = \Delta U'_{\tau 6} - (\Delta U'_{\tau 6} - \Delta U''_{\tau 6}) \frac{I - I'}{I'' - I'}. \tag{5-17}$$

where $\Delta U'_{\tau 6}$ - tabular value of the loss of voltage for minimum current I', o/o/A•km; $\Delta U''_{\tau 6}$ - the same for maximum current I", o/o/A•km; $\Delta U_{\tau 6}$ - loss of voltage for the intermediate current I, o/o/A•km.

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Example 5-4. To produce the calculation of line according to examples 5-1-5-3 with the aid of the tables of the specific losses of voltage.

Solution. 1. From example 5-1 great value M_a=9.44 kW•km. Permissible loss of voltage ΔU=4o/o.

We find computed value of the specific loss of voltage through (5-14):

$$\Delta U_{T6} < \frac{4}{9,44} = 0.425\ \%/\text{kW}\cdot\text{km}.$$

From Table 5-17 for aerial line 380/220 V with cos φ=1 we find the section of aluminum wire 70 mm² for which ΔU_{T6}=0.319o/o/kW•km.

We determine the loss of voltage in the main line AB on (5-13):

$$\Delta U_{AB} = 0,319 \cdot 8,56 = 2,73\ \%.$$

Computed values of the specific loss of voltage for the branching BV

$\Delta U_{т6} < \frac{4-2,73}{0,88} = 1,44$ %/kW•km;

for the branching BG

$\Delta U_{т6} < \frac{4-2,73}{0,78} = 1,63$ %/kW•km.

In both cases on Tables 5-17 we accept wire section 16 mm².

2. From example 5-2 $M_a = 3,05$ MW•km; ΔU=6.5%. On (5-14) we obtain:

$\Delta U_{т6} < \frac{6,5}{3,05} = 2,13$ %/MW•km.

On Tables 5-22 for the aluminum wire with cos φ=0.85 we find section 70 mm² for which $\Delta U_{т6} = 1,9$ %/MW•km.

Loss of voltage in the main line on (5-13)

$$\Delta U_{AB} = 1,9 \cdot 1,97 = 3,75\ \%.$$

The loss of voltage, permitted for the submains at point B, is equal to:

$$\Delta U_B = 6,5 - 3,75 = 2,75\ \%.$$

Computed values of the specific losses of the voltage: for the branching BV

$\Delta U_{т6} = \frac{2,75}{0,765} = 3,60$ %/MW•km (wire A35);

for the branching BG

$$\Delta U_{т6} = \frac{2{,}75}{1{,}08} = 2{,}54\ \%/\text{MW}\cdot\text{km} \text{ (wire A50)};$$

for the branching BD

$$\Delta U_{т6} = \frac{2{,}75}{0{,}92} = 3{,}0\ \%/\text{MW}\cdot\text{km} \text{ (wire A50)}.$$

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3. Permissible loss of voltage according to condition of example

ΔU=6.5•6 000/100=390 V.

The length of line is l=2.5 km.

Computed value of the specific loss of voltage on (5-16)

$$\Delta U_{т6} < \frac{390}{2{,}5} = 156 \text{ V/km}.$$

On Tables 5-20B for the current of line I=15 a we select the section of the wire of model ES-25 for which $\Delta U_{т6}$=151 V/km.

Example 5-5. From the transformer point of industrial enterprise obtains feed a main-line conductor ABV of the type ShMA 59-1, to which are connected distributive conductors BG, VD and VE of the type ShRA 60-6 (Fig. 5-3). The lengths of the sections of conductors and load of distributive conductors are shown in Fig. 5-3. Loads are distributed irregularly along the conductors. Nominal line voltage 380 V, coefficients of power loading cos ϕ=0.7.

To determine the loss of voltage in the conductors of up to the outermost points G, D, E.

Solution. We determine the moments/torques of resistive loads in the individual sections of conductor.

Main-line conductor: section AB 610•0.14=85.5 kW•km; section BV 360•0.03=10.8 kW•km.

Distributive conductors: section BG 250•0.065=16.2 kW•km; section VE 200•0.05=10 kW•km; section VD 160•0.04=6.4 kW•km.

(During the determination of moments/torques in the distributive conductor the evenly distributed load we consider concentrated in the middle of conductor).

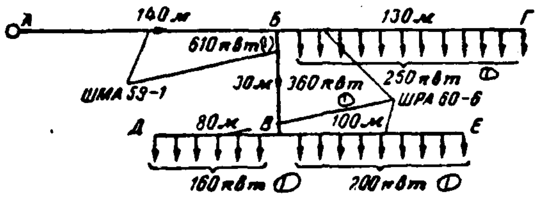

Fig. 5-3. Schematic of conductors for example 5-5.

Key: (1) KVM.

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From Table 5-28 for cos ϕ=0.7 we determine the values of the specific losses of the voltage: for the main-line conductor of the type ShMA 59-1 $\Delta U_{тб}=0{,}0308$ % /kW•km and for the distributive conductor of the type ShRA 60-6 $\Delta U_{тб}=0{,}133$ % /kW•km.

Using (5-13), we determine the loss of voltage of up to the end/lead G of distributive conductor BG:

$$\Delta U_{АГ}=0{,}0308\cdot 85{,}5+0{,}133\cdot 16{,}2=4{,}8\ \%.$$

We analogously determine the losses of voltage of up to the points D and E:

$$\Delta U_{АД}=3{,}82\ \%;\ \Delta U_{АЕ}=4{,}3\ \%.$$

Table 5-14. Loss of voltaye in the two-wire circuit of direct current cr two-wire circuit of alternating current with cos ϕ=1.

(1) Материал провода или жилы кабеля	(2) Номинальное сечение, мм²	(3) При номинальном напряжении, в						
		220	127	110	48	36	24	12
		%/квт·км (4)			%/квт·м (5)			
(6) Медь	1	77,7	233,0	311,0	1,63	2,90	6,52	26.1
	1,5	51,7	155,0	206,0	1,08	1,93	4,32	17.3
	2,5	31,1	93,3	125,0	0,653	1,16	2,61	10.4
	4	19,2	57,9	76,8	0,403	0.717	1,61	6,44
	6	12,7	38,1	50,6	0,265	0,472	1,06	4,24
	10	7,61	22,8	30,4	0,160	0.284	0,640	2,56
	16	4,96	14,9	19,8	0,104	0,185	0,416	1.66
	25	3,06	9,18	12,2	0,0642	0,114	0.257	1,03
	35	2,23	6,69	8,93	0,0468	0,0833	0,187	0,749
	50	1,61	4,83	6,45	0,0338	0,0602	0,135	0,541
	70	1,16	3,48	4,63	0,0243	0,0432	0,0972	0,389
	95	0,827	2,48	3,31	0,0173	0,0309	0,0692	0,277
(7) Алюминий	2,5	52,8	158,0	213,0	1,11	1,97	4,44	17,8
	4	33,1	99,3	132,0	0,693	1,23	2,77	11,1
	6	22,0	66,0	88,0	0,462	0,823	1,86	7,44
	10	13,2	39,6	52,8	0,277	0,494	1,11	4,43
	16	8,18	24,5	32,7	0,172	0,306	0,688	2,75
	25	5,29	15,9	21,2	0,111	0,198	0,444	1,78
	35	3,80	11,4	15,2	0,0798	0,142	0,319	1,28
	50	2,64	7,92	10,6	0,0555	0,0987	0,222	0,888
	70	1,90	5,70	7,60	0,0400	0,0710	0,160	0,640
	95	1,45	4,35	5,62	0,0236	0,0416	0,0944	0,378
	120	1,15	3,45	4,46	—	—	—	—

Key: (1). Material of wire cr cable core. (2). Nominal section, mm². (3). With nominal voltage, in. (4) 0/0/kW•km. (5) 0/0/kW•m. (6). Copper. (7). Aluminum.

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Table 5-15. Loss of voltage in three-phase line 380 V, performed by insulated wires on the rollers and the insulators, 0/0/kW•km.

(1) Материал провода	(2) Сечение провода, мм²	(3) При коэффициенте мощности										
		0,7	0,75	0,80	0,85	0,88	0,90	0,92	0,94	0,95	0,98	1,00
(4) Медь	1	13,2	13,2	13,2	13,1	13,1	13,1	13,1	13,1	13,1	13,1	13,0
	1,5	8,85	8,83	8,81	8,80	8,77	8,76	8,75	8,74	8,73	8,72	8,65
	2,5	5,39	5,37	5,35	5,33	5,32	5,31	5,31	5,30	5,28	5,27	5,21
	4	3,39	3,37	3,36	3,34	3,33	3,32	3,31	3,30	3,29	3,28	3,22
	6	2,29	2,27	2,25	2,23	2,22	2,21	2,21	2,20	2,19	2,18	2,12
	10	1,43	1,41	1,40	1,38	1,37	1,37	1,36	1,35	1,34	1,33	1,28
	16	0,993	0,965	0,958	0,941	0,931	0,924	0,916	0,908	0,899	0,887	0,831
	25	0,664	0,647	0,631	0,616	0,606	0,600	0,593	0,585	0,577	0,566	0,512
	35	0,527	0,510	0,494	0,478	0,469	0,462	0,455	0,448	0,439	0,428	0,374
	50	0,415	0,403	0,388	0,373	0,364	0,358	0,351	0,344	0,336	0,326	0,270
	70	0,365	0,346	0,328	0,310	0,299	0,292	0,284	0,275	0,266	0,254	0,196
	95	0,301	0,283	0,265	0,249	0,238	0,231	0,223	0,215	0,206	0,194	0,138
	120	0,267	0,249	0,233	0,216	0,207	0,199	0,192	0,184	0,175	0,164	0,109
(5) Алюминий	2,5	9,03	9,02	9,00	8,98	8,97	8,96	8,95	8,95	8,93	8,92	8,85
	4	5,71	5,69	5,67	5,65	5,64	5,63	5,62	5,61	5,60	5,59	5,54
	6	3,86	3,84	3,82	3,80	3,79	3,78	3,78	3,77	3,76	3,75	3,69
	10	2,37	2,35	2,34	2,32	2,31	2,31	2,30	2,29	2,28	2,27	2,22
	16	1,53	1,51	1,50	1,48	1,47	1,46	1,46	1,45	1,44	1,43	1,37
	25	1,04	1,02	1,01	0,990	0,980	0,974	0,967	0,959	0,951	0,940	0,886
	35	0,790	0,773	0,757	0,741	0,732	0,725	0,718	0,711	0,702	0,691	0,637
	50	0,588	0,573	0,558	0,543	0,534	0,528	0,521	0,514	0,506	0,496	0,443
	70	0,488	0,469	0,451	0,433	0,422	0,415	0,407	0,398	0,389	0,377	0,319
	95	0,398	0,380	0,362	0,346	0,335	0,328	0,320	0,312	0,303	0,291	0,235
	120	0,345	0,317	0,301	0,294	0,285	0,277	0,270	0,262	0,253	0,242	0,187
	150	0,298	0,281	0,265	0,249	0,240	0,233	0,226	0,219	0,210	0,199	0,145

Key: (1). Material of wire. (2). Section of wire, mm². (3). With power factor. (4). Copper. (5). Aluminum.

Table 5-16. Loss of voltage in three-phase cable line 380 V, 0/0 /kW•km.

(1) Материал жилы	(2) Номинальное сечение, мм²	(3) При коэффициенте мощности						
		0,70	0,75	0,80	0,85	0,90	0,95	1,00
(4) Медь	1	13,0	13,0	13,0	13,0	13,0	13,0	13,0
	1,5	8,72	8,71	8,70	8,69	8,68	8,67	8,65
	2,5	5,28	5,27	5,26	5,25	5,24	5,23	5,21
	4	3,29	3,28	3,27	3,26	3,25	3,24	3,22
	6	2,18	2,17	2,16	2,16	2,15	2,14	2,12
	10	1,33	1,32	1,32	1,31	1,30	1,30	1,26
	16	0,879	0,872	0,866	0,860	0,853	0,846	0,831
	25	0,559	0,552	0,546	0,540	0,534	0,527	0,512
	35	0,419	0,413	0,407	0,401	0,395	0,389	0,374
	50	0,314	0,308	0,302	0,297	0,291	0,284	0,270
	70	0,240	0,233	0,228	0,222	0,216	0,210	0,196
	95	0,181	0,175	0,169	0,164	0,158	0,152	0,138
	120	0,152	0,146	0,140	0,135	0,129	0,123	0,109
	150	0,127	0,122	0,116	0,111	0,105	0,099	0,085
	185	0,113	0,108	0,102	0,097	0,091	0,085	0,071
	240	0,100	0,090	0,085	0,079	0,074	0,067	0,054
(5) Алюминий	2,5	8,92	8,91	8,90	8,89	8,88	8,87	8,85
	4	5,61	5,60	5,59	5,58	5,57	5,56	5,54
	6	3,75	3,74	3,73	3,73	3,72	3,71	3,69
	10	2,27	2,26	2,26	2,25	2,24	2,24	2,22
	16	1,42	1,42	1,41	1,40	1,39	1,39	1,37
	25	0,933	0,926	0,920	0,914	0,908	0,901	0,886
	35	0,682	0,676	0,670	0,664	0,658	0,652	0,637
	50	0,487	0,481	0,475	0,470	0,464	0,457	0,443
	70	0,363	0,356	0,351	0,345	0,339	0,333	0,319
	95	0,277	0,272	0,266	0,261	0,255	0,249	0,235
	120	0,230	0,224	0,218	0,213	0,207	0,201	0,187
	150	0,187	0,182	0,176	0,170	0,165	0,159	0,145
	185	0,160	0,155	0,149	0,143	0,138	0,132	0,118
	240	0,133	0,128	0,122	0,117	0,111	0,104	0,092

Key: (1). Material of vein/strand. (2). Nominal section, mm². (3). With power factor. (4). Copper. (5). Aluminum.

Table 5-17. Loss of voltage in three-phase aerial line 380 V, %/kW•km.

(1) Материал провода	(2) Номинальное сечение, мм²	(3) При коэффициенте мощности										
		0,70	0,75	0,80	0,85	0,88	0,90	0,92	0,94	0,96	0,98	1,00
(4) Медь	4	3,51	3,47	3,43	3,40	3,37	3,36	3,34	3,33	3,30	3,28	3,22
	6	2,40	2,36	2,33	2,29	2,27	2,25	2,24	2,22	2,20	2,18	2,12
	10	1,55	1,51	1,48	1,44	1,42	1,41	1,39	1,38	1,36	1,33	1,28
	16	1,08	1,05	1,02	0,985	0,965	0,951	0,937	0,921	0,904	0,893	0,831
	25	0,756	0,723	0,692	0,660	0,641	0,628	0,614	0,599	0,582	0,572	0,512
	35	0,610	0,578	0,547	0,517	0,498	0,486	0,472	0,458	0,441	0,432	0,374
	50	0,498	0,467	0,438	0,409	0,390	0,378	0,365	0,351	0,335	0,326	0,270
	70	0,414	0,384	0,356	0,328	0,310	0,298	0,286	0,272	0,257	0,248	0,196
(5) Алюминий	16	1,62	1,59	1,55	1,52	1,50	1,49	1,47	1,46	1,44	1,42	1,37
	25	1,13	1,10	1,07	1,03	1,02	1,00	0,988	0,973	0,956	0,935	0,886
	35	0,873	0,841	0,811	0,781	0,762	0,749	0,736	0,721	0,705	0,684	0,637
	50	0,671	0,641	0,611	0,582	0,564	0,552	0,539	0,524	0,509	0,489	0,443
	70	0,539	0,509	0,481	0,453	0,435	0,423	0,411	0,397	0,382	0,362	0,319
	95	0,450	0,421	0,393	0,366	0,349	0,337	0,325	0,312	0,297	0,278	0,235
	120	0,395	0,367	0,340	0,314	0,297	0,286	0,274	0,261	0,247	0,228	0,187

Key: (1). Material of wire. (2). Nominal section, mm². (3). With power factor. (4). Copper. (5). Aluminum.

Table 5-18. Loss of voltage in three-phase cable line 660 V, %/kW•km.

(1) Материал жилы	(2) Номинальное сечение, мм²	(3) При коэффициенте мощности						
		0,70	0,75	0,80	0,85	0,90	0,95	1,00
Медь (4)	1	4,33	4,33	4.33	4,33	4,33	4.33	4.33
	1,5	2,91	2,90	2,90	2,90	2,89	2,89	2.88
	2,5	1,76	1,76	1,75	1,75	1,75	1,74	1,74
	4	1,10	1,10	1,09	1,09	1,08	1,08	1.07
	6	0,73	0,72	0,72	0,72	0,72	0,71	0,71
	10	0,444	0,440	0,440	0,437	0,433	0,431	0.428
	16	0,293	0,291	0,289	0,287	0,284	0,282	0.280
	25	0,186	0,184	0,182	0,180	0,181	0,176	0,171
	35	0,140	0,138	0,136	0,134	0,132	0,130	0,125
	50	0,105	0,103	0,101	0,099	0,097	0,095	0,090
	70	0,080	0,078	0,076	0,074	0,072	0,070	0,065
	95	0,060	0,058	0,056	0,054	0,052	0,050	0,046
	120	0,051	0,049	0,047	0,045	0,043	0,041	0,036
	150	0,042	0,041	0,039	0,037	0,035	0,033	0,028
	185	0,038	0,036	0,034	0,032	0,030	0,028	0,024
	240	0,033	0,030	0,028	0,026	0,024	0,022	0,018
Алюминий (5)	2,5	2,97	2,97	2,97	2,96	2,96	2,96	2,95
	4	1,87	1,87	1,87	1,86	1,86	1,85	1,85
	6	1,25	1,25	1,24	1,24	1,24	1,24	1,23
	10	0,76	0,75	0,75	0,75	0,75	0,75	0,74
	16	0,47	0,47	0,47	0,47	0,46	0,46	0,46
	25	0,311	0,309	0,307	0,305	0,303	0,300	0,295
	35	0,227	0,225	0,223	0,221	0,219	0,217	0,212
	50	0,162	0,16	0,158	0,157	0,155	0,152	0,148
	70	0,121	0,119	0,117	0,115	0,113	0,111	0,106
	95	0,092	0,091	0,089	0,087	0,085	0,083	0,078
	120	0,077	0,075	0,073	0,071	0,069	0,067	0,062
	150	0,062	0,061	0,059	0,057	0,055	0,053	0,048
	185	0,053	0,051	0,049	0,048	0,046	0,044	0,039
	240	0,044	0,043	0,041	0,039	0,037	0,035	0,030

Key: (1). Material of vein/strand. (2). Nominal section, mm². (3). With power factor. (4). Copper. (5). Aluminum.

Table 5-19. Loss of voltage in three-phase aerial line 660 V, $^0/_0$/kW•km.

(1) Материал провода	(2) Номинальное сечение, мм²	(3) При коэффициенте мощности										
		0,70	0,75	0,80	0,85	0,88	0,90	0,92	0,94	0,96	0,98	1,00
(4) Медь	4	1,17	1,16	1,14	1,13	1,12	1,12	1,11	1,11	1,10	1,09	1,07
	6	0,80	0,79	0,78	0,77	0,76	0,75	0,75	0,74	0,73	0,73	0,71
	10	0,52	0,50	0,49	0,48	0,47	0,47	0,46	0,46	0,45	0,44	0,42
	16	0,360	0,350	0,340	0,328	0,322	0,327	0,312	0,307	0,301	0,298	0,277
	25	0,252	0,241	0,231	0,220	0,214	0,209	0,205	0,200	0,194	0,191	0,171
	35	0,207	0,192	0,182	0,172	0,166	0,165	0,157	0,153	0,147	0,144	0,125
	50	0,166	0,157	0,146	0,136	0,130	0,129	0,122	0,117	0,112	0,109	0,090
	70	0,138	0,128	0,119	0,109	0,103	0,099	0,095	0,091	0,	0,083	0,065
(5) Алюминий	16	0,54	0,53	0,52	0,51	0,50	0,50	0,49	0,49	0,49	0,48	0,46
	25	0,377	0,370	0,357	0,343	0,340	0,333	0,329	0,324	0,319	0,312	0,295
	35	0,291	0,280	0,270	0,260	0,254	0,250	0,245	0,240	0,235	0,228	0,212
	50	0,227	0,217	0,204	0,194	0,188	0,184	0,180	0,175	0,170	0,163	0,148
	70	0,180	0,170	0,160	0,151	0,145	0,141	0,137	0,132	0,127	0,121	0,106
	95	0,150	0,140	0,131	0,122	0,116	0,112	0,108	0,104	0,099	0,092	0,078
	120	0,132	0,122	0,113	0,105	0,099	0,095	0,091	0,087	0,082	0,076	0,062

Key: (1). Material of wire. (2). Nominal section, mm². (3). With power factor. (4). Copper. (5). Aluminum.

Table 5-20A. Loss of vcltage in three-phase aerial line, made by steel wires, V/km.

(1) Ток линии, а	(2) При коэффициенте мощности											
	0,7						0,75					
	ПСО-3,5 (Ж-3,5)	ПСО-4 (Ж-4)	ПСО-5 (Ж-5)	ПС-25 ПМС-25	ПС-35 ПМС-35	ПС-50 ПМС-50	ПСО-3,5 (Ж-3,5)	ПСО-4 (Ж-4)	ПСО-5 (Ж-5)	ПС-25 ПМС-25	ПС-35 ПМС-35	ПС-50 ПМС-50
0,5	9,9	7,6	—	—	—	—	10,5	8,1	—	—	—	—
1	21,7	16,7	—	7,48	5,15	4,04	22,8	17,6	—	7,92	5,57	4,2
1,5	37,0	28,4	18,7	11,2	7,73	6,06	38,6	29,5	19,7	11,8	8,55	6,43
2	56,0	42,0	30,0	15,0	10,4	8,10	57,5	33,4	30,8	15,9	11,4	8,59
3	101	79,5	60,6	22,7	16,0	12,2	102	80,7	60,4	23,9	16,9	12,9
4	151	119	94,5	30,4	21,4	16,2	153	121	95,2	32,4	22,6	17,2
5	212	168	137	38,4	27,1	20,4	213	169	138	40,4	28,5	21,6
6	280	216	186	46,6	32,7	24,5	282	217	197	49,0	34,6	25,9
7	329	264	236	54,8	38,5	28,6	330	267	242	57,5	40,6	30,3
8	380	319	285	63,5	44,5	32,8	379	321	283	66,8	47,0	34,8
9	430	360	316	72,8	50,7	37,2	432	364	310	77,7	53,4	39,4
10	482	400	335	82,7	57,2	41,5	485	403	337	86,6	60,2	44,0
15	714	568	467	140	93,5	63,8	718	573	469	146	98,1	67,3
20	—	—	576	212	141	87,8	—	—	580	223	147	92,6
25	—	—	—	282	198	115	—	—	—	292	208	121
30	—	—	—	346	260	147	—	—	—	360	271	155
35	—	—	—	406	314	182	—	—	—	422	326	192
40	—	—	—	465	360	221	—	—	—	479	373	232
46	—	—	—	513	404	261	—	—	—	533	418	273
50	—	—	—	565	446	301	—	—	—	586	462	315
60	—	—	—	665	525	374	—	—	—	686	544	390
70	—	—	—	757	596	444	—	—	—	784	618	462

Key: (1). Current of line, a. (2). With power factor.

Table 5-20B. Loss of voltage in three-phase aerial line, made by steel wires, V/km.

(1) Ток линии, а	(2) При коэффициенте мощности											
	0.8						0.85					
	ПСО-3.5 (Ж-3.5)	ПСО-4 (Ж-4)	ПСО-5 (Ж-5)	ПС-25 ПМС-25	ПС-35 ПМС-35	ПС-50 ПМС-50	ПСО-3.5 (Ж-3,5)	ПСО-4 (Ж-4)	ПСО-5 (Ж-5)	ПС-25 ПМС-25	ПС-35 ПМС-35	ПС-50 ПМС-50
0,5	11,0	8,55	—	—	—	—	11,6	8,95	—	—	—	—
1	23,9	18,4	—	8,23	5,78	4,4	24,8	19,1	—	8,56	6,00	4,56
1,5	40,0	30,6	20,3	12,3	8,68	6,61	41,0	31,5	20,8	12,9	8,98	6,83
2	58,8	44,6	31,3	16,5	11,6	8,84	59,8	45,5	31,8	17,2	12,1	9,19
3	103	81,6	60,8	24,9	17,5	13,2	104	81,7	60,4	25,8	18,1	13,7
4	154	121	95,2	33,4	23,5	17,7	154	121	94,4	34,7	24,3	18,4
5	214	169	138	42,1	29,5	22,1	214	168	137	43,7	30,6	22,9
6	282	217	187	51	35,6	26,6	279	216	184	52,9	36,9	27,5
7	331	267	237	60	42	31,1	329	265	236	62,1	43,5	32,3
8	383	321	285	69,5	48,5	35,8	380	318	281	71,8	50,1	36,9
9	435	363	316	80,4	55,1	40,5	430	360	311	81,9	56,8	41,8
10	486	404	335	89,7	62	45,2	482	400	331	92,6	64	46,6
15	712	574	467	151	101	69	683	554	449	155	102	70,4
20	—	—	579	227	151	94,8	—	—	571	233	154	97,5
25	—	—	—	311	213	124	—		—	308	217	127
30	—	—	—	369	275	158	—	—	—	378	282	162
35	—	—	—	432	332	194	—	—	—	443	340	200
40	—	—	—	492	381	236	—	—	—	503	389	242
45	—	—	—	544	426	278	—	—	—	557	435	284
50	—	—	—	602	472	320	—	—	—	615	480	326
60	—	—	—	705	555	396	—	—	—	721	564	404
70	—	—	—	805	630	469	—	—	—	825	642	479

Key: (1). Current of line, A. (2). With power factor.

Table 5-20C. Loss of voltage in three-phase aerial line, made by steel wires, V/km.

(1) Ток. линии, а	(2) При коэффициенте мощности											
	0.9						0,95					
	ПСО-3.5 (Ж-3.5)	ПСО-4 (Ж-4)	ПСО-5 (Ж-5)	ПС-25 ПМС-25	ПС-35 ПМС-35	ПС-50 ПМС-50	ПСО-3.5 (Ж-3,5)	ПСО-4 (Ж-4)	ПСО-5 (Ж-5)	ПС-25 ПМС-25	ПС-35 ПМС-35	ПС-50 ПМС-50
0,5	12,1	9,39	—	—	—	—	12,6	9,75	—	—	—	—
1	25,7	19,8	—	8,89	6,23	4,73	26,4	20,5	—	9,14	6,40	4,85
1,5	42,1	32,4	20,4	13,3	9,33	7,08	42,6	33,0	21,5	13,6	9,59	7,26
2	60,5	46,2	32,0	17,8	12,4	9,46	60,5	46,4	31,9	18,4	12,8	9,71
3	104	81,5	59,9	26,9	18,8	13,5	102	79,4	57,8	27,5	19,0	14,5
4	152	120	92,9	35,9	25,2	19,0	148	116	89,3	36,9	25,7	19,4
5	212	166	134	45,3	31,6	23,7	210	159	129	46,6	32,4	24,2
6	276	212	182	54,7	38,2	28,5	265	204	174	56,1	39,1	29,1
7	323	261	230	64,1	44,9	33,2	312	250	220	66,0	46,0	34,0
8	374	313	275	74,4	51,8	38,2	361	301	262	76,2	53,2	39,2
9	422	353	304	84,5	58,5	43,1	408	340	291	86,9	60,2	44,1
10	474	393	325	95,6	66,1	48,1	455	377	308	97,7	67,5	49,3
15	685	560	451	159	106	73,3	650	539	431	161	108	74,8
20	—	—	560	239	158	100	—	—	537	243	160	102
25	—	—	—	315	223	131	—	—	—	318	224	132
30	—	—	—	386	287	166	—	—	—	389	288	167
35	—	—	—	467	345	205	—	—	—	455	346	206
40	—	—	—	512	396	246	—	—	—	515	396	248
45	—	—	—	569	442	289	—	—	—	572	443	290
50	—	—	—	627	488	333	—	—	—	629	448	333
60	—	—	—	729	573	410	—	—	—	741	574	413
70	—	—	—	839	650	485	—	—	—	847	652	487

Key: (1). Current, lines, A. (2). with coefficient of power.

Table 5-21. Loss of voltage in three-phase aerial line, made by steel wires, V/km, with cos ϕ=1.

(1) Ток линии, а	ПСО-3,5 (Ж-3,5)	ПСО-4 (Ж-4)	ПСО-5 (Ж-5)	ПС-25 ПМС-25	ПС-35 ПМС-35	ПС-50 ПМС-50
0,5	17,3	10,0	—	—	—	—
1	26,3	20,4	—	9,10	6,39	4,76
1,5	40,8	32,0	20,6	13,7	9,52	7,17
2	55,8	43,3	28,9	18,2	12,7	9,51
3	90,5	69,5	49,3	27,4	19,0	14,3
4	128	99	74,8	36,7	25,6	19,1
5	174	134	106	46,0	32,0	23,8
6	222	172	144	54,5	38,5	28,5
7	260	210	182	65,0	45,2	33,3
8	300	249	213	74,7	52,0	38,2
9	340	282	236	84,7	58,6	43,0
10	380	313	252	95,2	65,8	48,1
15	526	450	353	155	104	72,6
20	—	—	440	232	152	98,5
25	—	—	—	302	212	127
30	—	—	—	368	270	161
35	—	—	—	430	325	197
40	—	—	—	486	370	235
45	—	—	—	539	413	274
50	—	—	—	592	454	312
60	—	—	—	696	533	383
70	—	—	—	798	605	451

Key: (1). Current of line, A.

Table 5-22. Loss of voltage in three-phase aerial line 6 kV, 0/0/ W•km.

(1) Материал провода	(2) Номинальное сечение, мм²	(3) При коэффициенте мощности										
		0.7	0,75	0,80	0,85	0,88	0,90	0,92	0,94	0,93	0,98	1,00
(4) Медь	10	6,33	6,17	6,00	5,83	5,75	5,70	5,61	5,56	5,45	5,36	5,11
	16	4.48	4,34	4,18	4,03	3,94	3,88	3,81	3,74	3,66	3,56	3,33
	25	3,17	3,02	2,87	2,73	2,64	2,58	2,52	2,45	2,37	2,28	2,06
	35	2,58	2,43	2,29	2.16	2,07	2,01	1,95	1,88	1,81	1,71	1,50
	50	2,21	2,06	1,91	1,77	1,68	1.62	1,55	1,48	1,41	1,31	1,08
	70	1,88	1,73	1,59	1,45	1,36	1.30	1,24	1,17	1,09	1,00	1,778
(5) Алюминий	25	4,67	4,52	4,38	4,24	4,15	4,09	4,02	3,95	3,88	3,78	3,56
	35	3.64	3,49	3,35	3,21	3,13	3.07	3,01	2,94	2,87	2,77	2,56
	50	2,83	2,68	2,55	2,42	2,34	2,28	2,22	2,15	2,08	1,99	1,78
	70	2.30	2,16	2,03	1,90	1,82	1,76	1,71	1,64	1,57	1,48	1,28
	95	2,02	1,87	1,73	1,60	1,51	1,45	1,39	1,33	1,25	1,16	0,947
	120	1,80	1,66	1,52	1,39	1,31	1,25	1,19	1,12	1,05	0,96	0.75

Key: (1). Material of wire. (2). Nominal section, mm². (3). With power factor. (4). Copper. (5). Aluminum.

Table 5-23. Loss of voltage in three-phase aerial line 10 kV, 0/0/MW•km.

(1) Материал провода	(2) Номинальное сечение, мм²	(3) При коэффициенте мощности										
		0,7	0,75	0,80	0,85	0,88	0,90	0,92	0,94	0,96	0,98	1,00
(4) Медь	10	2,28	2,22	2,16	2,10	2,07	2,05	2,02	2,00	1,96	1,93	1,84
	16	1,61	1,56	1,50	1,05	1,41	1,39	1,37	1,35	1,32	1,28	1,2
	25	1,14	1,09	1,03	0,984	0,952	0,93	0,907	0,883	0,855	0,82	0,74
	35	0,929	0,876	0,826	0,776	0,745	0,724	0,702	0,678	0,651	0,617	0,54
	50	0,796	0,741	0,688	0,637	0,605	0,583	0,56	0,534	0,506	0,471	0,39
	70	0,676	0,622	0,571	0,521	0,489	0,468	0,445	0,421	0,393	0,359	0,28
(5) Алюминий	25	1,68	1,63	1,57	1,52	1,49	1,47	1,45	1,42	1,39	1,36	1,28
	35	1,31	1,26	1,21	1,16	1,12	1,10	1,08	1,06	1,03	0,997	0,92
	50	1,02	0,966	0,917	0,869	0,839	0,819	0,798	0,774	0,748	0,715	0,64
	70	0,827	0,778	0,730	0,683	0,654	0,634	0,613	0,591	0,565	0,533	0,46
	95	0,725	0,673	0,623	0,574	0,543	0,522	0,501	0,477	0,450	0,417	0,34
	120	0,647	0,596	0,547	0,499	0,470	0,449	0,428	0,404	0,378	0,345	0,27

Key: (1). Material of wire. (2). Nominal section, mm². (3). With power factor. (4). Copper. (5). Aluminum.

Table 5-24. Loss of voltage in the three-phase cable line 6 kV, %/MW•km.

(1) Материал жилы	(2) Номинальное сечение, мм²	(3) При коэффициенте мощности										
		0.70	0,75	0,80	0.85	0,88	0,90	0.92	0.94	0.96	0.98	1,00
(4) Медь	10	5,39	5,35	5,31	5,28	5,26	5,24	5,22	5,21	5,19	5,16	5,11
	16	3,64	3,59	3,56	3,53	3,50	3,48	3,47	3,45	3,42	3,39	3,33
	25	2,32	2,29	2,25	2,22	2,20	2,18	2,17	2,15	2,14	2,11	2,06
	35	1,75	1,72	1,68	1,65	1,64	1,62	1,60	1,59	1,57	1,55	1,50
	50	1,32	1,28	1,25	1,22	1,20	1,19	1,18	1,17	1,15	1,13	1,08
	70	1,00	0,980	0,943	0,915	0,895	0,884	0,873	0,860	0,842	0,822	0,778
	95	0,767	0,740	0,711	0,683	0,667	0,656	0,645	0,631	0,617	0,598	0,556
	120	0,651	0,623	0,595	0,567	0,550	0,538	0,528	0,513	0,500	0,481	0,438
	150	0,545	0,517	0,492	0,467	0,450	0,438	0,428	0,413	0,400	0,384	0,342
	185	0,481	0,456	0,430	0,406	0,389	0,378	0,365	0,356	0,342	0,325	0,286
	240	0,428	0,400	0,372	0,345	0,328	0,317	0,306	0,292	0,278	0,258	0,217
(5) Алюминий	10	9,18	9,14	9,10	9,07	9,05	9,03	9,01	9,00	8,98	8,95	8,90
	16	5,81	5,75	5,72	5,70	5,67	5,65	5,64	5,61	5,58	5,56	5,50
	25	3,83	3,78	3,75	3,73	3,70	3,69	3,68	3,66	3,64	3,61	3,56
	35	2,80	2,77	2,74	2,71	2,69	2,68	2,66	2,65	2,63	2,61	2,56
	50	2,01	1,98	1,95	1,92	1,90	1,89	1,87	1,86	1,85	1,83	1,78
	70	1,50	1,48	1,44	1,41	1,39	1,38	1,37	1,36	1,34	1,32	1,28
	95	1,16	1,13	1,10	1,07	1,05	1,04	1,03	1,02	1,00	0,986	0,947
	120	0,961	0,933	0,906	0,878	0,861	0,850	0,839	0,826	0,811	0,792	0,750
	150	0,786	0,758	0,733	0,708	0,692	0,681	0,670	0,656	0,642	0,626	0,584
	185	0,667	0,642	0,617	0,592	0,576	0,564	0,553	0,541	0,528	0,511	0,472
	240	0,578	0,550	0,522	0,495	0,478	0,467	0,455	0,442	0,428	0,408	0,367

Key: (1). Material of vein/strand. (2). Nominal section, mm². (3). With power factor. (4). Copper. (5). Aluminum.

Table 5-25. Loss of voltage in the three-phase cable line 10 kV, 0/0/MW•km.

(1) Материал жилы	(2) Номинальное сечение, мм²	(3) При коэффициенте мощности										
		0,70	0,75	0,80	0,85	0,88	0,90	0,92	0,94	0,96	0,98	1,00
(4) Медь	16	1,31	1,29	1,28	1,27	1,26	1,25	1,25	1,24	1,23	1,22	1,20
	25	0,836	0,823	0,810	0,798	0,790	0,785	0,780	0,774	0,767	0,759	0,74
	35	0,630	0,618	0,606	0,595	0,588	0,583	0,577	0,572	0,566	0,558	0,54
	50	0,474	0,462	0,451	0,441	0,434	0,430	0,425	0,420	0,414	0,407	0,39
	70	0,361	0,353	0,339	0,329	0,322	0,318	0,314	0,309	0,303	0,296	0,28
	95	0,276	0,266	0,256	0,246	0,240	0,236	0,232	0,227	0,222	0,215	0,20
	120	0,234	0,224	0,214	0,204	0,198	0,194	0,190	0,185	0,180	0,173	0,158
	150	0,196	0,186	0,177	0,168	0,162	0,158	0,154	0,149	0,144	0,138	0,123
	185	0,173	0,164	0,155	0,146	0,140	0,135	0,132	0,128	0,123	0,117	0,103
	240	0,154	0,144	0,134	0,124	0,118	0,114	0,110	0,105	0,100	0,093	0,078
(5) Алюминий	16	2,09	2,07	2,06	2,05	2,04	2,03	2,03	2,02	2,01	2,00	1,98
	25	1,38	1,36	1,35	1,34	1,33	1,32	1,32	1,31	1,31	1,30	1,28
	35	1,01	0,998	0,986	0,975	0,968	0,963	0,957	0,952	0,946	0,938	0,92
	50	0,724	0,712	0,701	0,691	0,684	0,680	0,675	0,670	0,664	0,657	0,64
	70	0,541	0,533	0,519	0,509	0,502	0,498	0,494	0,489	0,483	0,476	0,46
	95	0,416	0,406	0,396	0,386	0,380	0,376	0,372	0,367	0,362	0,355	0,34
	120	0,346	0,336	0,326	0,316	0,310	0,306	0,302	0,297	0,292	0,285	0,27
	150	0,283	0,273	0,264	0,255	0,249	0,245	0,241	0,236	0,231	0,225	0,21
	185	0,240	0,231	0,222	0,213	0,207	0,203	0,199	0,195	0,190	0,184	0,17
	240	0,208	0,198	0,188	0,178	0,172	0,168	0,164	0,159	0,154	0,147	0,132

Key: (1). Material of vein/strand. (2). Nominal section, mm². (3). With power factor. (4). Copper. (5). Aluminum.

Table 5-26. Loss of voltage in three-phase conductor 380 V, performed by the aluminum busbars of rectangular cross section, %/kW•km.

(1) Размеры шин, мм	(2) При коэффициенте мощности							
	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
25×3	0,848	0,690	0,590	0,533	0,468	0,421	0,374	0,289
30×4	0,716	0,567	0,474	0,417	0,355	0,310	0,266	0,186
40×4	0,640	0,501	0,414	0,362	0,304	0,262	0,221	0,146
40×5	0,609	0,471	0,386	0,333	0,276	0,235	0,194	0,117
50×5	0,560	0,429	0,348	0,288	0,245	0,206	0,167	0,097
50×6	0,541	0,413	0,332	0,283	0,229	0,190	0,152	0,082
60×6	0,508	0,384	0,308	0,262	0,210	0,174	0,137	0,0705
80×6	0,455	0,382	0,272	0,229	0,182	0,148	0,144	0,0535
100×6	0,417	0,312	0,247	0,208	0,163	0,131	0,102	0,0439
60×8	0,485	0,364	0,288	0,242	0,192	0,155	0,119	0,0535
80×8	0,437	0,325	0,256	0,212	0,168	0,134	0,102	0,0412
100×8	0,404	0,300	0,235	0,196	0,152	0,121	0,090	0,0338
120×8	0,373	0,275	0,215	0,178	0,138	0,109	0,0803	0,0284
80×10	0,430	0,318	0,249	0,207	0,161	0,127	0,0950	0,0343
100×10	0,392	0,290	0,226	0,187	0,144	0,113	0,0830	0,0276
120×10	0,367	0,270	0,209	0,173	0,117	0,104	0,0747	0,0229

Note. The values of the losses of voltage are given with temperature of +30°C and distance between centers of busbars 250 mm.

Key: (1). Sizes/dimensions of busbars, mm. (2). With power factor.

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Table 5-27. Loss of voltage in three-phase conductor 380 V, carried out by the steel busbars of rectangular cross section, %/A•km.

(1) Размеры шины, мм	(2) Ток линии, а	(3) При коэффициенте мощности							
		0,6	0,65	0,7	0,75	0,8	0,85	0,9	0,95
40×3	35 70	1,95 1,78	2,00 1,82	2,03 1,86	2,06 1,87	2,08 1,89	2,09 1,90	2,07 1,88	2,02 1,84
50×3	40 95	1,62 1,46	1,66 1,48	1,69 1,52	1,71 1,53	1,73 1,54	1,77 1,54	1,72 1,53	1,68 1,49
60×3	50 100	1,35 1,25	1,38 1,27	1,40 1,29	1,42 1,30	1,43 1,31	1,44 1,32	1,42 1,30	1,38 1,27
80×3	70 110	1,05 1,00	1,07 1,02	1,09 1,03	1,10 1,04	1,11 1,05	1,11 1,05	1,10 1,04	1,05 1,01
100×3	80 130	0,860 0,800	0,675 0,815	0,887 0,825	0,895 0,830	0,900 0,835	0,895 0,830	0,885 0,812	0,885 0,790
40×4	40 65	1,76 1,69	1,80 1,74	1,84 1,75	1,86 1,78	1,88 1,79	1,89 1,79	1,87 1,78	1,83 1,74
50×4	50 85	1,46 1,33	1,49 1,36	1,52 1,38	1,54 1,40	1,56 1,41	1,57 1,41	1,55 1,40	1,52 1,37

Key: (1). Sizes/dimensions of busbar, mm. (2). Current of line, A. (3). With power factor.

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Table 5-28. Loss of voltage in the conductors with the aluminum busbars of series ShRA and ShMA with voltage 380 V, $^{0}/_{0}$/kW•km.

(1) Тип токопровода	(2) При коэффициенте мощности												
	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0,75	0.8	0.85	0.9	0.95	1.00
ШРА 60-2	0.432	0,394	0,362	0,335	0,313	0,291	0,272	0,256	0,239	0,223	0,206	0,187	0,146
ШРА 60-4	0,345	0,311	0,284	0,259	0,238	0,220	0,203	0,188	0,173	0,160	0,145	0,127	0.091
ШРА 60-6	0,230	0,208	0,188	0,171	0,158	0,145	0,133	0,124	0,113	0,103	0,092	0,081	0.056
ШМА 59-1	0,0485	0,0443	0,0407	0,0378	0,0352	0,0329	0,0308	0,0289	0,0271	0,0253	0,0234	0,0212	0,0167
ШМА 59-2	0,0428	0,0388	0,0352	0,0322	0,0296	0,0274	0,0253	0,0233	0,0215	0,0197	0,0178	0,0157	0,0111
ШМА 59-4	0,0388	0,0346	0,0310	0,0280	0,0255	0,0232	0,0211	0,0192	0,0173	0,0155	0,0137	0,0115	0,0070

Key: (1). Type of conductor. (2). With power factor.

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5-6. Calculation of net according to the loss of voltage and the condition for the smallest expenditure of metal.

For the main-line multiended line at the end/lead (Fig. 5-4) the section of the wires of main line according to the condition for the smallest expenditure of metal is determined from the formula

$$F_a = a_1 \frac{M_{aa}}{\Delta U_a}\left(1 + \sqrt{\frac{\sum_1^n M_a L}{M_{aa} L}}\right), \qquad (5\text{-}18)$$

where α_1 - a coefficient in Table 5-9;

M_{aa} - sum of the products of resistive loads on the lengths of the sections of the main line;

L_n - length of the main line;

ΔU_a - permissible loss of voltage in the line with the resistive loads;

$\sum_{1}^{n} M_i L$-the sum of the products of values M_i for the length of branching, calculated for all branchings.

The obtained on (5-18) section of main line is rounded off before the nearest (greater or smaller) standard section of wire.

The determination of the sections of wires for the branchings is conducted according to the formulas § 5-2 and 5-3.

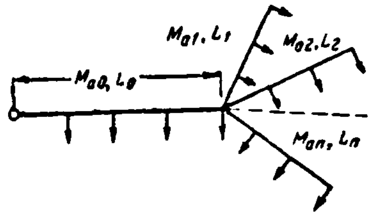

Fig. 5-4. Schematic of main line with the branchings at the end/lead.

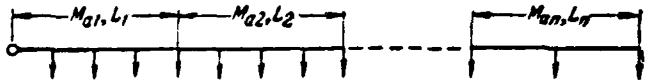

Fig. 5-5. Schematic of main line, made from several sections of different sections.

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For trunk line, divided along the length on several sections (Fig. 5-5), section of the first section are determined from the formula

$$F_1 = \alpha_1 \frac{M_{a1}}{\Delta U_a} \cdot \frac{\sum_1^n \sqrt{M_a L}}{\sqrt{M_{a1} L_1}}, \quad (5\text{-}19$$

where α_1 - the coefficient, determined in Table 5-9;

M_{a1} - value M_a for the first section;

L_1 - length of the first section;

ΔU_a - permissible loss of voltage for the entire length with the resistive loads.

The obtained on (5-19) section of the wires of the first section is rounded off before the nearest (greater or smaller) standard section.

The section of the wires of the second section is determined from the formula

$$F_2 = a_1 \frac{M_{a2}}{\Delta U_a - \Delta U_{a1}} \cdot \frac{\sum_2^n \sqrt{M_a L}}{M_{a2} L_2}, \quad (5\text{-}20)$$

in which indices 1 and 2 noted the values, which relate respectively to the first and second sections of line.

The sections of the wires of the subsequent sections are determined analogously.

The section of the wires of latter/last section is rounded off toward larger nominal section.

In the cases of calculating the lines taking into account the inductance of wires values ΔU_a, ΔU_{a1}, ΔU_{a2} and so forth in (5-18), (5-19) and (5-20) are determined on (5-10).

Example 5-6. To calculate from the loss of voltage and the condition for the smallest expenditure of metal line from example 5-2.

Solution. According to the data of example 5-2 we have:

$$\Delta U = 6{,}5\%;\ \Delta U_a = 4{,}4\%;\ a_1 = 87{,}5\ \text{ом}\cdot\text{мм}^2/\text{м}\cdot\text{кв}^2;$$
$$M_{a0} = M_{aАБ} = 1{,}97\ \text{Мвт}\cdot\text{км};\ L_0 = 2\ \text{км};$$
$$M_{a1} = M_{aБВ} = 0{,}765\ \text{Мвт}\cdot\text{км};\ L_1 = 9\ \text{км};$$
$$M_{a2} = M_{aБГ} = 1{,}08\ \text{Мвт}\cdot\text{км};\ L_2 = 4\ \text{км};$$
$$M_{a3} = M_{aБД} = 0{,}92\ \text{Мвт}\cdot\text{км};\ L_3 = 6\ \text{км}.$$

Key: (1). Ω•mm²/m•kV². (2). MW•km.

whence we determine the section of main line AB on (5-18):

$$F_0 = 87{,}5\frac{1{,}97}{4{,}4}\left(1+\sqrt{\frac{0{,}765\cdot 9+1{,}08\cdot 4+0{,}92\cdot 6}{1{,}97\cdot 2}}\right) = 119\ \text{мм}^2\ (120\ \text{мм}^2).$$

Further calculation we perform according to the data by table 5-22.

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Loss of voltage in the main line

$$\Delta U_{АБ} = \Delta U_0 = 1{,}39\cdot 1{,}97 = 2{,}74\ \%.$$

Loss of voltage, permitted during the calculation of branching from the point B,

$$\Delta U_Б = 6{,}5 - 2{,}74 = 3{,}76\ \%.$$

Calculation of the brancnings:

tranching BV

$$\Delta U_{тб} < \frac{3,76}{0,765} = 4,92\ \% \text{ (провод}^{(1)} \text{ A25);}$$

Key: (1). wire.

tranching BG

$$\Delta U_{тб} < \frac{3,76}{1,08} = 3,48\ \% \text{ (wire A35);}$$

tranching BD

$$\Delta U_{тб} < \frac{3,76}{0,92} = 4,1\ \% \text{ (wire A35).}$$

Here $\Delta U_{тб}$ - tabular value cf tne magnitude cf lcsses of vcltage. The weight of tha wires cf line according tc the calculaticn cf example 5-2 (see Table 2-2)

$$G_1 = 3(191 \cdot 2 + 95 \cdot 9 + 136 \cdot 4 + 136 \cdot 6) = 7\,791 \text{ кг.}^{(1)}$$

Key: (1). kg.

Weight of wires acccrding to the calculaticn fcr the minimum cf the metal

$$G_2 = 3(322 \cdot 2 + 68 \cdot 9 + 95 \cdot 4 + 95 \cdot 6) = 6\,618 \text{ кг.}^{(1)}$$

Key: (1). kg.

Weight saving of wires during the calculaticn for the minimum of the metal

7791—6618=1173 (1) кг (2) (или 15%).

Key: (1). kg. (2). or.

5-7. Calculation of net according to the loss of voltage and the condition of permanent current density.

The sections of the wires of the individual sections of net during the calculation according to the loss of voltage according to the condition of permanent current density are determined from the formulas:

$$F_1 = \frac{I_1}{j};\ F_2 = \frac{I_2}{j}, \qquad (5\text{-}21)$$

where I_1, I_2, the currents of the sections of line, a; j - current density, constant for all sections of the line:

$$j = \frac{\gamma \Delta U_a}{\sqrt{3}\ \Sigma l \cos\varphi}; \qquad (5\text{-}22)$$

γ - specific conductivity of wire, m/Ω•mm²; ΔU_a - permissible loss of voltage in the line with the resistive loads.

During the calculation of line taking into account inductance ΔU_a it is determined from formula (5-10).

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$\Sigma l \cos\varphi$ - the sum of the products of the length of each of the sections in the meters to the power factor - is computed from the beginning of line to the end/lead of that branching for which this

sum is greatest.

With identical cos φ for all loads of line the current density is determined from the formula

$$j=\frac{\gamma\Delta U_{a}}{\sqrt{3}L\cos\varphi},\qquad(5\text{-}23)$$

where L - the overall length, equal to the length of main line and to the maximum length of branching, m.

The calculated on (5-21) sections of wires are rounded off before the nearest nominal section, after which is conducted the verifying calculation of line on the magnitude of losses of voltage.

5-8. Loss of voltage in the transformer.

Loss voltage in the windings of double wound transformer is determined from the formulas:

$$\Delta U_{т}=\frac{PR+QX}{U}=\frac{S}{U}(R\cos\varphi+X\sin\varphi),\ \text{кв}^{(1)};\qquad(5\text{-}24)$$

$$\Delta U_{т\%}=\frac{PR+QX}{UU_{н}}\cdot 100=\frac{S}{U}\cdot\frac{R\cos\varphi+X\sin\varphi}{U_{н}}\cdot 100,\ \%,\qquad(5\text{-}25)$$

Key: (1). kV.

where P - the resistive load of transformer, MW;

Q - the reactive load of transformer, Mvar;

S - the full load of transformer, MVA;

U - load voltage of transformer, kV;

$U_н$ - nominal line voltage, kV;

cos ϕ - coefficient of power loading of the transformer;

R - the effective resistance of the windings of the transformer;

$$R=\left(\frac{U_{н.т}}{S_н}\right)^2 \Delta P_{к.з.}\ ом^{(1)}; \qquad (5\text{-}26)$$

Key: (1). ohm.

X - reactance of the windings of the transformer:

$$X=\frac{U^2_{н.т}}{S_н}\cdot\frac{U_x}{100},\ ом. \qquad (5\text{-}27)$$

In formulas (5-26) and (5-27):

$S_н$ - the nominal power of transformer, MVA; $U_{н.т}$ - nominal voltage of the windings of transformer, kV; $\Delta P_{к.з}$ - loss of short circuit in transformer, MW; U_x - voltage drop, o/o, in the reactance of transformer, determined according to formula (9-7).

In formulas (5.24), (5.25), (5.26) and (5.27) all values must be

related either to the side of the highest (VN), or to the side lowest (NN) voltage.

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Tables 9-2, 9-3 and 9-4 give the values of the active and reactance of transformers with respect to the side VN. The translation of these resistors/resistances with respect to the side NN is conducted according to the formulas:

$$R_{HH} = \frac{R_{BH}}{n^2}, \text{ (1) } om; \tag{5-28}$$

$$X_{HH} = \frac{X_{BH}}{n^2}, \text{ (1) } om, \tag{5-29}$$

Key: (1) Ω.

where n - a transformation ratio of the transformer:

$$n = \dot{U}_T n_n, \tag{5-30}$$

where $\dot{U}_T$ - relative value of voltage, which corresponds to this branching of the winding VN; n_n - the nominal transformation ratio of transformer.

The magnitudes of losses of voltage in the transformers with the nominal load and nominal load voltage for different power factors are given in Table 5-29.

Example 5-7. To determine the losses of voltage in the transformer 10/0.4 kV with a power of 630 by kVA with the diagram of connections of windings Y/Y_n-0, if the load of transformer S=500 of kVA

with cos ϕ=0.85, branching of the winding of transformer - 5c/o the value of voltage on the secondary side of transformer U=0.39 kV.

From Table 9-2 for the transformer of 630 kVA, 10/0.4 kV we find the active and reactance of the windings of transformer through the relation to side VN:

$$R_{BH} = 1,91\ \Omega;$$
$$X_{BH} = 8,52\ \Omega.$$

The nominal transformation ratio of transformer is equal to:

$$n_T = \frac{10}{0,4} = 25.$$

Actual transformation ratio taking into account the selected branching of windings is determined from formula (5-30):

$$n = 0,95 \cdot 25 = 23,8.$$

We recount the resistors/resistances of transformer with respect to the side NN according to formulas (5-28) and (5-29):

$$R_{HH} = \frac{1,91}{23,8^2} = 0,00338\ \overset{(1)}{ом};$$

$$X_{HH} = \frac{8,52}{23,8^2} = 0,015\ \overset{(1)}{ом}.$$

Key: (1) Ω.

Nominal line voltage on the side NN of the transformer

$$U_н = 0,38\ кв.$$

For cos ϕ=0.85 sin ϕ=0.527.

The loss of voltage in the transformer we determine from formula (5.25):

$$\Delta U_T = \frac{0,5}{0,39} \cdot \frac{0,00338 \cdot 0,85 + 0,015 \cdot 0,527}{0,38} \cdot 100 = 3,7\ \%.$$

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Table 5-29. Loss of voltage, o/c in the step-down transformers 6-35/C.4/0.23 kV with the ncminal load.

(1) Номинальная мощность трансформатора, ква	(2) Номинальное напряжение обмотки ВН, кв	(3) При коэффициенте мощности										
		0,7.	0,75	0,8	0,85	0,88	0,9	0,92	0,94	0,96	0,98	1.0
25	6—10	4,39	4,31	4,20	4,04	3,92	3,82	3,70	3,55	3,37	3,11	2,40
40	6—10	4,34	4,24	4,11	3,94	3,80	3,69	3,56	3,41	3,21	2,94	2,20
63	6—10	4,29	4,18	4,04	3,84	3,70	3,58	3,44	3,28	3,08	2,80	2,03
63	20	4,68	4,54	4,36	4,13	3,96	3,82	3,66	3,47	3,23	2,90	2,03
100	6—10	4,27	4,15	4,01	3,81	3,66	3,54	3,40	3,23	3,02	2,74	1,97
100	20—35	5,80	5,57	5,29	4,94	4,67	4,47	4,24	3,96	3,62	3,16	1,97
160	6—10	4,16	4,02	3,85	3,62	3,46	3,32	3,17	2,99	2,77	2,46	1,66
160	20—35	5,65	5,40	5,10	4,72	4,44	4,23	3,99	3,70	3,35	2,88	1,66
250	6—10	4,07	3,92	3,73	3,50	3,32	3,18	3,03	2,84	2,61	2,30	1,48
250	20—35	5,55	5,29	4,98	4,59	4,31	4,09	3,84	3,55	3,19	2,71	1,48
400	6—10	4,02	3,86	3,67	3,42	3,24	3,10	2,94	2,75	2,52	2,20	1,38
400	20—35	5,51	5,24	4,92	4,52	4,23	4,01	3,76	3,46	3,10	2,61	1,37
630	6—10	4,67	4,45	4,18	3,85	3,61	3,42	3,21	2,96	2,66	2,25	1,20
630	20—35	5,40	5,12	4,79	4,39	4,09	3,87	3,61	3,31	2,94	2,45	1,21
1 000	6—10	4,68	4,46	4,19	3,86	3,62	3,44	3,22	2,97	2,67	2,26	1,22
1 000	20—35	5,41	5,13	4,80	4,40	4,10	3,88	3,62	3,32	2,96	2,46	1,22
1 600	6—10	4,62	4,39	4,12	3,78	3,54	3,35	3,14	2,89	2,58	2,17	1,12
1 600	20—35	5,36	5,07	4,74	4,33	4,03	3,80	3,54	3,24	2,87	2,38	1,12

Note. Table is comprised for the transformers, prepared according to GOST 12022-66 and 11920-66.

Key: (1). Nominal power of transformer, kVA. (2). Nominal voltage of winding VN, kV. (3). With power factor.

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Section Six.

SELECTION OF CONDUCTORS ON THE THERMAL AND DYNAMIC STABILITY TO THE CURRENT SHORT CIRCUIT.

Conductors and conductors in electrical networks are above 1000 V, as a rule, are subject to checking to the conditions heatings by current short circuit.

In electrical networks to 1000 V to the thermal resistance are checked only the conductors.

An increase in the temperature of the cores of the isolated/insulated conductors and cables as a result of the passage of current short circuit leads to the chemical decomposition of insulation and a sharp decrease in its electrical and mechanical strength and, consequently, also to the possibility of emergency. Therefore are established/installed the specific maximum permissible limits of the temperatures in the mode/conditions the short circuits, indicated in Table 6-1.

Checking cables for the heating from the currents short circuit must be conducted:

1) for the single cables of small extent, on the basis of the short circuit the beginning of the cable;

2) for the single cables, which have the couplings, on the basis of the short circuit in the beginning of each section, in order to have the capability by steps/stages to decrease the section of cable over its length;

3) for two and the more in parallel connected cables, on the basis of the short circuit it is direct after the beam (on the through current).

It is allowed/assumed not to check conductors under the conditions short circuit in the case of their protection by safety fuses. Line is considered shielded by the safety device/fuse when the disconnecting ability of safety device/fuse is sufficient for the cutoff/disconnection of the greatest possible emergency current of line.

For the lines to the individual electrical receivers, including to the shop transformers in total power to 1000 kVA inclusively, it

is allowed/assumed nct tc check the section cf conductors on the current short circuit with the simultanecus cbservance of the following conditions:

1. In the electrical or technclogical part is provided redundancy, which guarantees from the discrder cf preduction process.

2. Injury of conductors with short circuit cannot produce blast.

3. Is possible replacement cf conductors without considerable difficulties.

For the lines tc the individual electrical receivers or small distribution pcints cf ncncritical destinaticn it is allowed/assumed nct tc produce checking conductcrs to the thermal resistance with the short circuit, if is prcvided cnly one ccnditicn 2 (absence of explosion hazard).

The wires of aerial lines to 10 kV are nct checked using the current short circuit.

The permissible strengths cf current short circuit for the cables are determined in depending on material and section of cable and duration of the passage of current short circuit.

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The thermal action of current short circuit during the real transit time of its t_{A} is characterized by the value of fictitious time t_{ϕ} passage of steady current short circuit with the identical with respect to thermal action effect.

Fictitious time is determined (on curves [13, page 92]) in depending on the relation

$$\beta'' = \frac{I''}{I_{\infty}}, \qquad (6\text{-}1)$$

where I" - the effective value of periodic component of current short circuit into initial moment, a; I_{∞} - steady current short circuit (effective value), a.

Real time t_{A} is composed from time element, established/installed on maximum-current protection line, and proper time of the disconnecting apparatus (switch of power).

During the checking by the thermal resistance of conductors of lines, equipped by the high speed automatic reset, must be considered an increase in the heating conductors due to an increase in the total duration short circuit.

During calculations current short circuit in distribution networks 6-10 kV very frequently the attenuation does not consider. In this case fictiticus time can be accepted by the equal to real and the problem of checking the conductors to the thermal resistance is simplified by the absence of the need of determining the fictitious time.

The section, which ensures the thermal resistance of conductor to the current short circuit with the assigned magnitude of fictitious time t_ϕ is determined from the expression

$$F = I_\infty \frac{\sqrt{t_\phi}}{C}, \qquad (6\text{-}2)$$

where F - a section of the cable core, mm²; C - constant, determined in depending on the assigned by PUE final temperature of heating of core and the voltage; numerical values to the constant C were shown in Table 6-1.

Is given below Table 6-2 for checking the cables to the thermal resistance, comprised according to formula (6-2) in the values of permissible steady current short circuit in the kiloamperes.

In addition to calculation for the thermal resistance the section of the busbars of conductors must be checked also to the

mechanical strength with the short circuit (dynamic stability of conductor).

Table 6-3 gives the data, necessary for testing the dynamic stability of the busbars or the conductors of series ShRA and ShMA.

Example to 6-1. It is necessary to select cable 6 kV with the aluminum veins/strands, thermally resistant to the current short circuit $I_\infty=5$ kA, assuming that the attenuation short circuit virtually is absent. Time element of maximum protection from the side of the point/item of feed 0.5 s.

Solution. In the practical absence of attenuation fictitious time can be accepted by the equal to real, and the latter is composed from time element of the maximum protection of line and proper time of oil breaker and relay which in the sum can be accepted equal to 0.25 s.

$$t_\phi=t_n=0{,}5+0{,}25=0{,}75\ s.$$

Consequently,

Being turned to Table 6-2, for the time of 0.75 s we determine that to cable with the aluminum veins/strands by section 3x50 mm² corresponds the permissible strength of current the short circuit of 5.6 kA, i.e. with the given values $I_\infty=5$ kA cable will prove to be

thermostable.

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The same we can obtain directly from (6-2):

$$F = 5 \cdot 1\,000 \cdot \frac{\sqrt{0,75}}{98} = 44 \text{ мм}^2.$$

Example 6-2. What maximum time element should be established/installed on the oil breaker of the feeding line, made by the cable of brand SB section 3x70 mm² with the steady short circuit of closing/shorting 11 kA?

Attenuation, as in the preceding/previous example, we assume/set by virtually absentee.

Solution. On tables 6-2 in the graph/count for the copper cable by section 70 mm² we find the value of current the short circuit, which exceeds the assigned magnitude. We have 11.7 kA. This corresponds to the fictitious time of 0.75 s. Consequently, assuming that the proper time of the switch of power and relay, as in the first example, it will not exceed 0.25 s, we are convinced, that maximum time element of the protection of line, so that the cable would remain resistant to the thermal action of current short circuit, it must not exceed 0.5 s.

Example 6-3. In the shop of industrial enterprise runs itself distributive conductor with the aluminum busbars. Design load of conductor 350 A; conductor it is shielded by a selective automatic switch of the type AV-4S, the tripping time of which with the short circuit is equal to 0.6 s. The current strengths with the short circuit conductor comprise:

periodic component of prompt current short circuit, equal to steady current (attenuation is absent) 12 kA;

the amplitude of prompt current the short circuit of 22 kA.

It is necessary to fit the type of conductor.

Solution. According to the condition of heating by calculated current it would be possible to accept a conductor of the type ShRA 60-4 to rated current 400 A, but the dynamic stability of the conductor indicated was insufficient (see Table 6-3): 10 ka<22 kA.

The condition for dynamic stability answers the following type of conductor ShRA 60-6 rated current 600 A, for which the value of the permissible amplitude of current short circuit is 25 kA: 25>22 kA.

We check a conductor of the type ShPA 60-6 against the thermal resistance with respect to (6-2). According to the condition of the example:

$$I_{\infty} = 12 \text{ ka} = 12\,000 \text{ a};$$

$$t_{\phi} = t_{n} = 0.6 \text{ s}$$

(Fictitious time is accepted by the equal to real tripping time short circuit, since the attenuation of current short circuit is absent).

Value of constant C for the aluminum busbars is determined on Table 6-1:

$$C = 90.$$

The minimum section of the busbars of conductor according to the conditions for thermal resistance with the short circuit is equal to:

$$F = 12\,000 \cdot \frac{\sqrt{0.6}}{90} = 103 \text{ mm}^2.$$

The selected type of conductor satisfies the condition for thermal resistance, since the section of busbars for it comprises $60 \times 6 = 360 \text{ mm}^2 > 103 \text{ mm}^2$.

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Table 6-1. Permissible temperatures of heating the conductors also of busbars with the short circuit.

(1) Вид и материал проводника	(2) Наибольшая допустимая температура, °C	(3) Значение коэффициента C
(4) Шины медные	300	165
(5) Шины алюминиевые	200	90
(6) Шины стальные, не имеющие непосредственного соединения с аппаратом	400	66
(7) Шины стальные с непосредственным соединением с аппаратом	300	60
(8) Кабели с бумажной пропитанной изоляцией напряжением до 10 *кв* с медными и алюминиевыми жилами	200	$\frac{98}{145}$
(9) Кабели и изолированные провода с полихлорвиниловой или резиновой изоляцией с медными и алюминиевыми жилами	150	$\frac{83}{122}$
(10) Медные голые провода при тяжениях менее 2 $кГ/мм^2$	250	165
(11) То же при тяжениях более 2 $кГ/мм^2$ . . .	200	145
(12) Алюминиевые голые провода при тяжениях менее 1 $кГ/мм^2$	200	98
(13) То же при тяжениях более 1 $кГ/мм^2$ . . .	160	85
(14) Алюминиевая часть сталеалюминиевых проводов	200	98

Notes: 1. The values of value C are determined with mean operating temperatures of 75°C for the busbars and by 50°C for the wires and and cables.

2. In numerators of fractions are shown values of value C for aluminum, in denominators - for copper.

Key: (1). Form and material of conductor. (2). Greatest permissible

temperature. (3). Value of coefficient. (4). Busbars (copper. (5). Busbars (aluminum. (6). Busbars steel, which do not have direct connection with apparatus. (7). Busbars steel with direct connection with apparatus. (8). Paper-insulated cables voltage to 10 kV with copper and aluminum veins/strands. (9). Cables and insulated wires with polychlorovinyl or rubber insulation with copper and aluminum veins/strands. (10). Copper bare wires with stresses are less than 2 kg/mm^2. (11). Then with stresses is more than 2 kg/mm^2. (12). Aluminum bare wires with stresses are less than 1 kg/mm^2. (13). Then with stresses is more than 1 kg/mm^2. (14). Aluminum part of steel-aluminum wires.

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Table 6-2. Permissible strengths of current the short circuit of cables with the paper insulation to the voltage 6-10 kV according to the conditions of thermal resistance, kA.

$t_в$	(1) Сечение кабелей, мм²								
	16	25	35	50	70	95	120	150	185
	(2) Алюминиевые жилы								
0,25	3,12	4,88	6,85	9,75	13,70	18,50	23,40	29,25	36,00
0,5	2,20	3,45	4,80	6,90	9,65	13,00	16,50	20,00	25,45
0,75	1,80	2,80	3,95	5,60	7,90	10,65	13,50	16,90	20,50
1,0	1,56	2,44	3,40	4,85	6,80	9,25	11,80	14,60	18,00
1,5	1,28	2,00	2,80	4,00	5,55	7,55	9,55	11,90	14,75
2,0	1,10	1,72	2,40	3,45	4,80	6,55	8,25	10,30	12,75
2,5	0,985	1,54	2,16	3,08	4,30	5,85	7,40	9,20	11,40
3,0	0,90	1,40	1,97	2,80	3,95	5,35	6,75	8,40	10,40
3,5	0,83	1,30	1,80	2,60	3,65	4,95	6,25	7,80	9,60
4,0	0,78	1,24	1,70	2,44	3,40	4,65	5,85	7,30	9,00
4,5	0,73	1,15	1,60	2,30	3,20	4,35	5,50	6,90	8,50
5,0	0,70	1,10	1,52	2,18	3,00	4,15	5,23	6,53	8,10
5,5	0,66	1,04	1,45	2,10	2,90	3,95	5,00	6,23	7,70
6,0	0,640	1,00	1,40	2,00	2,80	3,80	4,80	6,00	7,35
	(3) Медные жилы								
0,25	4,63	7,25	10,2	14,5	20,2	27,5	34,8	43,5	53,5
0,5	3,28	5,12	7,16	10,4	14,3	19,5	24,6	30,7	38,0
0,75	2,68	4,19	5,85	8,37	11,7	15,9	20,0	25,0	31,0
1,0	2,32	3,63	5,00	7,25	10,1	13,8	17,4	21,8	26,8
1,5	1,90	2,96	4,15	5,92	8,30	11,3	14,2	17,8	21,9
2,0	1,64	2,56	3,58	5,12	7,18	9,72	12,3	16,6	19,0
2,5	1,47	2,30	3,20	4,58	6,42	8,71	11,0	13,8	17,0
3,0	1,34	2,10	2,93	4,19	5,86	7,95	10,0	12,6	15,5
3,5	1,24	1,94	2,71	3,88	5,43	7,36	9,30	11,6	14,4
4,0	1,16	1,81	2,50	3,62	5,05	6,90	8,70	10,9	13,4
4,5	1,09	1,70	2,39	3,41	4,78	6,48	8,20	10,2	12,6
5,0	1,04	1,62	2,27	3,25	4,55	6,16	7,80	9,75	12,0
5,5	0,99	1,55	2,16	3,09	4,32	5,86	7,40	9,25	11,4
6,0	0,95	1,48	2,07	3,06	4,15	5,63	7,10	8,88	11,0

Key: (1). Section of cables. (2). Aluminum veins/strands. (3). Copper veins/strands.

Table 6-3. Values of the permissible impact current short circuit for the conductors with the aluminum busbars of series ShRA and ShMA.

(1) Тип токопровода	(2) Размеры шин, мм	(3) Номинальный ток, а	(4) Динамическая устойчивость, ка
ШРА 60-2	30×5	250	10
ШРА 60-4	50×5	400	10
ШРА 60-6	60×6	600	25
ШМА 59-1	2×100×8	1 500	40
ШМА 59-2	2×120×10	2 500	50
ШМА 59-4	2×160×12	4 000	70

Key: (1). Type of conductor. (2). Sizes/dimensions of busbars. (3). Rated current, A. (4). Dynamic stability, kA.

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Section Seven.

Testing the conditions for functioning shielding apparatus during the single-phase closing/shorting in the nets by voltage to 1000 V with the dead ground of neutral.

In electrical networks by voltage to 1000 V with the dead ground of neutral must be provided reliable cutoff/disconnection with shielding apparatus single-phase short circuit. This is dictated by the requirements of safety engineering.

Calculation points for determining the strength of current short circuit are the outermost (in the electrical sense) points of net, since to precisely these points corresponds the small value of current single-phase short circuit.

The value of single-phase current short circuit can be determined according to the approximation formula

$$I_{к} = \frac{U_{ф}}{Z_{т} + Z_{п}}, \qquad (7\text{-}1)$$

where $U_{ф}$ - phase line voltage, in; $Z_{т}$ - impedance of step-down current transformer of contact to frame vault ohm; $Z_{п}$ - impedance of

loop phase - zero lines to the outermost point of net, ohm.

Computed values impedances of the step-down transformers during the single-phase closings/shortings are given in Table 7-1.

For the transformers whose power is more than 630 kVA during the determination of current short circuit it is possible to accept:

$$Z_{т}=0.$$

Impedance of the loop of wires or cable cores of line is determined from the formula

$$Z_{п}=\sqrt{R_{п}^{2}+X_{п}^{2}}, \quad (7\text{-}2)$$

where $R_{п}$ - the effective resistance of phase ($R_{ф}$) and zero (R_{0}) of wires, ohm;

$$R_{п}=R_{ф}+R_{0}; \quad (7\text{-}3)$$

$X_{п}$ - inductive reactance of the loop of wires or core of cable, ohm.

The effective resistance of wires from the nonferrous metals are determined on Table 5-1. The average/mean values of inductive reactances of the loops of wires or cores of cables from the nonferrous metals on 1 km of line they were given in Table 7-2.

For the steel wires inductive reactance of the loop of wires is determined from the formula

$$X_{п}=X_{п}'+X''_{в.ф}+X''_{в.о}. \quad (7\text{-}4)$$

where $X'_{н}$ - external inductive reactance of loop from the straight/direct and return conductors, equal for aerial line by voltage to 1000 V of 0.6 Ω/km; $X''_{в.п}$ and $X''_{в.о}$ - internal inductive reactances of the respectively straight/direct and return conductors of line, Ω/km.

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Table 7-1. Calculated resistors/resistances of transformers with the single-phase short circuit on the side 400/230 V.

ГОСТ	(1) Тип	(2) Номинальная мощность, *ква*	(3) Напряжение обмотки ВН, *кв*	(4) Схема соединений	(5) Полное сопротивление $Z_Т$, *ом*
401-41	ТМ, ТМА	20	6—10	$У/У_н$	1,39
	ТМ	30	6—10	$У/У_н$	0,9
	ТМ	50	6—10	$У/У_н$	0,54
	ТМ	100	6—10	$У/У_н$	0,27
	ТМА	100	35	$У/У_н$	0,25
	ТСМА	100	6—10	$У/У_н$	0,26
	ТСМ	100	35	$У/У_н$	0,25
	ТМ, ТМА	180	6—10	$У/У_н$	0,15
	ТМ, ТМА	180	35	$У/У_н$	0,14
	ТМ, ТМА	320	6—10	$У/У_н$	0,085
	ТМ, ТМА	320	35	$У/У_н$	0,08
	ТМ, ТМА	560	6—10	$У/У_н$	0,048
	ТМ, ТМА	560	35	$У/У_н$	0,046
	ТМ, ТМА	750	6—10	$У/У_н$	0,036
	ТМ, ТМА	1 000	6—10	$У/У_н$	0,027
	ТМ	1 000	35	$У/У_н$	0,026
12022-66	ТМ	25	6—10	$У/У_н$	1,04
	ТМ	40	6—10	$У/У_н$	0,65
	ТМ	63	6—10	$У/У_н$	0,413
	ТМ	63	20	$У/У_н$	0,38
	ТМ	100	6—10	$У/У_н$	0,26
	ТМ	100	20—35	$У/У_н$	0,253
	ТМ	160	6—10	$У/У_н$	0,162
	ТМ	160	20—35	$У/У_н$	0,159
	ТМ	250	6—10	$У/У_н$	0,104
	ТМ	250	20—35	$У/У_н$	0,102
	ТМ	400	6—10	$У/У_н$	0,065
	ТМ	400	20—35	$У/У_н$	0,064
	ТМ	400	6—10	$Д/У_н$	0,022
	ТМ	630	6—10	$У/У_н$	0,043
	ТМ	630	20—35	$У/У_н$	0,04
	ТМ	630	6—10	$Д/У_н$	0,014
11920-66	ТМ	1 000	6—10	$У/У_н$	0,027
	ТМ	1 000	20—35	$У/У_н$	0,026
	ТМ	1 000	6—10	$Д/У_н$	0,009
	ТМ	1 000	20—35	$Д/У_н$	0,01
—	ТСЗ	160	6—10	$Д/У_н$	0,055
	ТСЗ	180	6—10	$У/У_н$	0,15
	ТСЗ	250	6—10	$Д/У_н$	0,035
	ТСЗ	320	6—10	$У/У_н$	0,085
	ТСЗ	400	6—10	$Д/У_н$	0,022
	ТСЗ	560	6—10	$У/У_н$	0,048
	ТСЗ	630	6—10	$Д/У_н$	0,014
	ТСЗ	750	6—10	$У/У_н$	0,036
	ТСЗ	1 000	6—10	$Д/У_н$	0,009
	ТСЗ	1 000	6—10	$У/У_н$	0,027

Notes: 1. Table is comprised on the basis of materials [22].

2. For step-down transformers with voltage of secondary windings 230/133 V the values of resistors/resistances are 3 times less than indicated in Table 7-1.

3. Conventional designations of diagrams of connections of transformers: Y - star; Y_0 - star with derived zero point; D - triangle.

Key: (1). Type. (2). Nominal power, kVA. (3). Voltage of winding VN, kV. (4). Connection diagram. (5). Impedance Z_T, ohm.

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Active and internal inductive reactances for the steel wires are determined from Table 5-4 in depending on the strength of calculated minimum current short circuit.

The values impedances of loops for the wires of cores of cables from the nonferrous metals on 1 km of line they were given in Table 7-3, and for the steel stranded wires - in Table 7-4.

Table 7-5 gives the resistors/resistances of loop "phase - zero" for aluminum triple-cores cable in alumirum shell during the use by the latter as the neutral conductor.

Table 7-6 shows the resistors/resistances of loop the "phase of triple-core cable - steel strip" for unarmoured cables.

Table 7-2. The average/mean values of inductive reactances of the locp of straight/direct and return conductors or core of cable, made frcm nonferrous metals Ω/км.

(1) Условия прокладки	(2) Индуктивные сопротивления
(3) Кабель до 1 *кв* или провода, проложенные в трубах	0,15
(4) Изолированные провода на роликах	0,4
(5) Провода на изоляторах внутри помещений или по наружным стенам здания	0,5
(6) Воздушные линии низкого напряжения	0,6

Key: (1). Conditions of separatcr. (2). Inductive reactances. (3). Cable to 1 kV or wires, laid in tubes. (4). Insulated wires cn rollers. (5). Wires cn insulatcrs indoors or cn external walls of building. (6). Aerial lines cf lcw voltage.

Table 7-3. Impedances of the loop of the straight/direct and return conductor of line or core of cable, Ω/km.

(1) Сечение провода, мм²		(2) Кабель и провода в трубах		(3) Провода на роликах и изоляторах		(4) Провода воздушных линий	
(5) прямого	(6) обратного	(7) медные	(8) алюминиевые	(7) медные	(8) алюминиевые	(7) медные	(8) алюминиевые
1	1	37,8	—	—	—	—	—
1,5	1	31,5	—	—	—	—	—
1,5	1,5	25,2	—	25,2	—	—	—
2,5	1,5	20,2	—	20,2	—	—	—
2,5	2,5	15,1	25,2	15,1	25,2	—	—
4	1,5	17,3	—	17,3	—	—	—
4	2,5	12,2	20,5	12,2	20,5	—	—
4	4	9,3	15,8	9,3	15,8	9,3	—
6	2,5	10,6	17,9	10,6	17,9	—	—
6	4	7,71	13,2	7,71	13,2	—	—
6	6	6,12	10,5	6,14	10,5	6,16	—
10	4	6,50	11,1	6,52	11,1	—	—
10	6	4,90	8,42	4,92	8,42	4,96	—
10	10	3,68	6,32	3,71	6,32	3,75	—
16	6	4,26	7,24	4,28	7,24	4,32	—
16	10	3,04	5,14	3,08	5,15	3,13	—
16	16	2,40	3,96	2,45	3,99	2,52	4,03
25	10	2,58	4,44	2,62	4,46	2,69	4,50
25	16	1,94	3,26	1,98	3,30	2,08	3,34
25	25	1,49	2,56	1,55	2,60	1,68	2,66
35	10	2,38	4,08	2,42	4,11	2,48	4,15
35	16	1,74	2,90	1,79	2,96	1,87	3,00
35	35	1,09	1,84	1,16	1,90	1,29	1,96
50	16	1,60	2,62	1,65	2,66	1,74	2,70
50	25	1,14	1,92	1,21	1,97	1,32	2,03
50	50	0,793	1,29	0,890	1,36	1,05	1,44
70	25	1,03	1,74	1,11	1,80	1,24	1,86
70	35	0,833	1,39	0,927	1,45	1,08	1,53
70	70	0,58	0,932	0,706	1,03	0,896	1,13
95	35	0,755	1,27	0,856	1,34	1,02	1,42
95	50	0,608	0,99	0,712	1,08	0,915	1,18
95	95	0,428	0,797	0,566	0,815	0,772	0,907
120	50	0,568	0,922	—	—	0,858	1,09
120	70	0,461	0,745	—	—	0,792	0,945
120	120	0,350	0,561	—	—	0,732	0,808
150	50	0,535	0,862	—	—	—	1,04
150	70	0,430	0,687	—	—	—	0,808
150	150	0,285	0,446	—	—	—	0,732

Key: (1). Section of wire. (2). Cable and wires in tubes. (3). Wires on porcelain insulators and insulators. (4). Wires of aerial lines. (5). straight line. (6). reverse/inverse. (7). copper. (8). aluminum.

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In the electrical devices with dully grounded neutral the admittance of the grounding conductors taking into account the natural grounding electrodes must comprise not less than 50o/c conductivity of the phase conductor of most powerful/thickest line from a number feeding this electrical device or separate electrical receivers.

In all cases the sections of grounding conductors must be not below minimally permissible, given in Table 7-7.

The grounding conductors, specially intended for this purpose, must run itself together, also, in immediate proximity of the phase conductors. During the use of the natural grounding conductors they must be arranged/located also in immediate proximity to the phase conductors.

With the wiring steel tubes or execution of line armored cable by most reliable is the use for the grounding of the fourth core of wire or cable.

Table 7-4. Impedances cf the lccp cf the straight/direct and return conductors of aerial lines by vcltage to 1000 V with steel stranded wires, Ω/km.

(1) Марка проводов		(2) Номинальный ток плавкой вставки, а							
(3) прямого	(4) обратного	6	10	15	20	30	40	50	60
		(5) Ток уставки автоматического выключателя с электромагнитным расцепителем, а							
		12	20	30	40	60	60	100	120
ПС-25	ПС-25	13,5	15,0	14,6	14,1	13,4	—	—	—
ПС-35	ПС-35	8,72	11,1	11,3	11,0	10,3	9,70	9,20	—
ПС-50	ПС-25	9,61	10,7	11,0	11,0	10,7	—	—	—
ПС-50	ПС-50	5,72	6,45	7,42	9,90	7,90	7,65	7,42	7,33
ПС-70	ПС-25	8,50	9,32	9,22	9,16	9,05	—	—	—
ПС-70	ПС-35	6,15	7,37	7,60	7,60	7,50	7,26	7,06	—
ПС-70	ПС-70	3,58	3,64	3,85	4,23	4,70	4,82	4,93	4,65

Key: (1). Brand of wires. (2). Rated current by smelting insert, A. (3). straight line. (4). reverse/inverse. (5). Current of setting cf automatic switch with electrcmagnetic release, A.

Table 7-5. Impedances of the locp "phase zerc" cf three-strand aluminum cables during the use cf their aluminum shells as neutral conductor, Ω/km.

(1) Сечение жилы кабеля, мм²	16	25	35	50	70	95	120
(2) Сопротивление петли „фаза—нуль", ом	2,58	1,84	1,39	1,03	0,806	0,635	0,543

Key: (1). Section of catle ccre. (2). Resistcr/resistance cf loop "phase zerc", ohm.

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Reliable cutoff/disconnection with shielding apparatus single-phase short circuit will be provided under the condition of fulfilling the relationship/ratio

$$K_{зн} I_з \leq I_к, \qquad (7\text{-}5)$$

where $K_{зн}$ - permissible multiplicity of minimum current short circuit with respect to the rated current by smelting the insert of safety device/fuse either to spill current or to rated current of the maximum release of the automatic machine $I_з$; $I_к$ - the smallest value of single-phase current the short circuit, determined according to formula (7-1), A.

In accordance with the requirements PUE the permissible multiplicity of minimum current short circuit must be not less than 3 with respect to the rated current smelting the insert of safety device/fuse and the rated current of the release of the automatic switch, which has the conversely dependent on the current characteristic, and not less than $1.1 K_р$ with respect to the spill current of the automatic switch, which has only electromagnetic release ($K_р$ - coefficient, which calculates the spread of the characteristics of release on the basis of the data of plant).

Table 7-6. Impedances cf lccp tne "phase of three vein/strand cable - steel strip", Ω/km.

(1) Сечение кабеля, мм²	(2) Ток и материал жил кабеля	(3) Размеры стальной полосы, мм: 20×4		40×4		50×4	50×4	60×4		80×4		100×4, 100×6	100×5, 100×8
	(4) Ток срабатывания максимального расцепителя автомата, а	150	1 400	200	1 400	250	1 400	300	1 400	400	1 400	500	1 400
	(5) Номинальный ток плавкой вставки безынерционного предохранителя, а	60	600	80	600	100	600	120	600	150	608	200	600
	(6) Материал жил кабеля:	(7) Полное сопротивление петли, ом/км											
3×4	(8) Медь	9,59	8,42	7,82	7,45	7,40	7,17	7,14	6,92	6,82	6,59	6,56	6,45
	(9) Алюминий	13,52	12,35	11,79	11,42	11,37	11,14	11,13	10,91	0,81	10,58	10,56	10,45
3×6	Медь	7,76	6,59	5,97	6,60	5,54	5,31	5,27	5,05	4,95	4,72	4,68	4,57
	Алюминий	10,34	9,17	8,59	8,22	8,17	7,94	7,92	7,7	7,61	7,38	7,34	7,23
3×10	Медь	6,36	5,19	4,55	4,18	4,11	3,98	3,83	3,61	3,5	3,27	3,22	3,1
	Алюминий	7,86	6,69	6,07	5,7	5,63	5,4	5,37	5,15	5,05	4,82	4,77	4,66
3×16	Медь	5,6	4,43	3,78	3,41	3,32	3,09	3,04	2,82	2,71	2,48	2,42	2,31
	Алюминий	6,49	5,32	4,68	4,31	4,24	3,01	3,96	3,74	3,64	3,41	3,36	3,25
3×25	Медь	5,14	3,97	3,31	2,94	2,86	2,63	2,57	2,35	2,24	2,01	1,95	1,84
	Алюминий	5,70	4,53	3,88	3,51	3,43	3,2	3,15	2,93	2,82	2,59	2,53	2,42
3×35	Медь	4,91	3,74	3,09	2,71	2,64	2,4	2,35	2,13	2,01	1,78	1,73	1,62
	Алюминий	5,30	4,13	3,48	3,11	3,03	2,8	2,74	2,52	2,41	2,18	2,12	2,01
3×50	Медь	4,75	3,58	2,92	2,55	2,47	2,24	2,19	1,97	1,86	1,63	1,57	1,46
	Алюминий	5,02	3,85	3,19	2,72	2,74	2,5	2,45	2,23	2,12	1,89	1,83	1,72
3×70	Медь	4,64	3,47	2,81	2,44	2,37	2,4	2,08	1,86	1,75	1,52	1,46	1,35
	Алюминий	4,83	3,66	3,0	2,63	2,55	2,32	2,26	2,04	1,93	1,7	1,64	1,53
3×95	Медь	4,57	3,40	2,73	2,36	2,29	2,06	2,01	1,79	1,67	1,44	1,38	1,27
	Алюминий	4,70	3,53	2,87	2,50	2,42	2,19	2,14	1,92	1,8	1,57	1,51	1,40
3×120	Медь	4,51	3,34	2,69	2,32	2,24	2,01	1,96	1,74	1,63	1,4	1,35	1,24
	Алюминий	4,62	3,45	2,8	2,43	2,35	2,12	2,07	1,85	1,74	1,51	1,45	1,34
3×150	Медь	4,47	3,30	2,65	2,28	2,21	1,98	1,93	1,71	1,60	1,37	1,31	1,2
	Алюминий	4,56	3,39	2,74	2,37	2,29	2,06	2,01	1,79	1,65	1,47	1,39	1,28
3×185	Медь	4,44	3,27	2,63	2,26	2,18	1,95	1,90	1,68	1,58	1,35	1,28	1,17
	Алюминий	4,52	3,35	2,7	2,33	2,25	2,02	1,96	1,74	1,64	1,41	1,35	1,24

Note. The resistor/resistance of locp the "phase of cable - steel strip" does not remain ccrstant for the indicated in the table values of current, since the resistcr/resistance of resistance is determined by interpolaticn.

Key: (1). Section of cacle. (2). Current and material of ccre of

cable. (3). Sizes/dimensions of steel strip. (4). Spill current of maximum release of automatic machine, A. (5). Rated current by smelting insert of inertia-free safety device/fuse, A. (6). Material of core of cable. (7). Impedance or loop, Ω/km. (8). Copper. (9). Aluminum.

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For the nets, run in the dangerously explosive locations, the permissible multiplicities of current short circuit increase to value of 4 with respect to the rated current by smelting the insert of safety device/fuse and 6 with respect to the rated current of the release of automatic switch with the conversely dependent on the current characteristic.

For the nets, shielded only from the currents short circuit, in the necessary cases (for example, for the tuning cut from the currents of the self-start of engines) is allowed/assumed the overestimate of the currents of the fuse links of safety devices/fuses and settings of the releases of automatic machines in comparison with the values, indicated in Table 4-50, but in this case the multiplicity of current short circuit must have a value not less than 5 with respect to the rated current by smelting the insert of safety device/fuse and not less than 1.5 with respect to the spill

current of the electromagnetic release of automatic machine.

The values of the permissible multiplicity of current short circuit for the varied conditions of the separator of net are given in Table 7-8.

Example to 7-1. Fig. 7-1 depicts the schematic of four-wire aerial line, made by aluminum wires and that obtaining feed from the busbars of the distributing frame 380/220 V. The neutral of system is dully grounded. The sections of wires and length of the sections of line are shown in Fig. 7-1.

Disregarding the resistor/resistance of external net to the busbars of panel and the resistor/resistance of transformer, to check the action of shielding apparatuses with the single-phase short circuit at the outermost points of line under the condition for fulfilling requirements PUE (see Table 4-50) for the following versions:

1. Line is shielded by safety devices/fuses with the fuse links to the rated current 80 A.

2. Line is shielded by automatic switch of type A 3124 with combined releases to rated current 100 A.

Table 7-7. Minimum sections of the copper and aluminum grounding conductors in the electrical devices to 1000 V.

(1) Наименования проводников	(2) Сечения проводников, мм²	
	(3) медных	(4) алюминиевых
(5) Голые проводники при открытой прокладке	4	6
(6) Изолированные провода	1,5	2,5
(7) Заземляющие жилы кабелей или многожильных проводов, находящихся в общей защитной оболочке с фазными жилами	1	1,5

Key: (1). Designations of conductors. (2). Sections of conductors. (3). copper. (4). aluminum. (5). Bare conductors with surface work. (6). Insulated wires. (7). Grounding cable cores or stranded wires, which are located in general/common/total shielding shell with phase veins/strands.

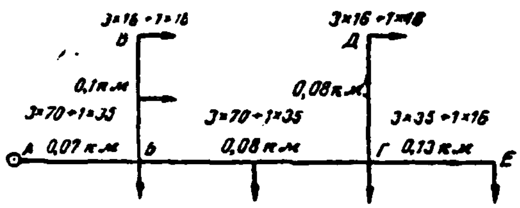

Fig. 7-1. Diagram for example to 7-1.

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3. Line is shielded by automatic switch of type A 3124 with electromagnetic releases with setting of spill current 600 A [1].

FOOTNOTE [1]. The considerations, according to which is selected one or another protector, here are not examined. An example has the limited target of - showing the typical cases of testing the shielding cutoff/disconnection with the single-phase short circuit. ENDFOOTNOTE.

Solution. The condition for functioning protectors we check according to formula (7-5). We determine the resistors/resistances of the loop of the phase and neutral conductors of line with the single-phase short circuit at such point for which the value of resistor/resistance it will be greatest. Through tables 7-3 we find the values of the specific resistors/resistances of loop "phase - zero" for the sections of the sections of the line:

$$3 \times 70 + 1 \times 35 \quad z_{n} = 1{,}53 \text{ ом/км}; \ (1)$$
$$3 \times 35 + 1 \times 16 \quad z_{n} = 3{,}0 \text{ ом/км}; \ (1)$$
$$3 \times 16 + 1 \times 16 \quad z_{n} = 4{,}03 \text{ ом/км}. \ (1)$$

Key: (1). Ω/km.

Table 7-8. Values of the permissible minimum multiplicity of current short circuit with respect to the current of shielding apparatus.

(1) Условия прокладки	(2) Допустимая кратность тока к. з. по отношению		
	(3) к номинальному току плавкой вставки предохранителя	(4) к току уставки срабатывания автоматического выключателя, имеющего только электромагнитный расцепитель (отсечку)	(5) к номинальному току расцепителя автоматического выключателя с обратно зависимой от тока характеристикой
(6) Сеть проложена в невзрывоопасном помещении при условии выполнения требований табл. 4-50	3	$1.1K_p$	3
(7) Сеть проложена в невзрывоопасном помещении при условии, что требования табл. 4-50 не выполняются	5	1,5	—
(8) Сеть проложена во взрывоопасном помещении . . .	4	$1.1K_p$	6

Notes: 1. K_p - coefficient, which considers the spread of the characteristics of automatic switches with the electromagnetic release.

2. In the absence of data of plant about guaranteed accuracy of setting of spill current of automatic switch with electromagnetic release (cutoff) it is allowed/assumed to take value of coefficient K_p for automatic switches for rated current to 100 A equal to 1.4, higher than 100 A - equal to 1.25.

3. With difficulty in fulfilling of requirements of those indicated in Table 7-8, is allowed/assumed use/application of

high-speed protection from closing/shorting to the earth.

Key: (1). Conditions of separator. (2). Permissible multiplicity of current short circuit according to relation. (3). to rated current by smelting insert of safety device/fuse. (4). to current of setting of functioning automatic switch, which has only electromagnetic release (cutoff). (5). to rated current of release of automatic switch with conversely dependent on current characteristic. (6). Net is laid in nonexplosive location under condition for fulfilling requirements tables 4-50. (7). Net is laid in nonexplosive location when requirements table 4-50 are not made. (8). Net is laid in dangerously explosive location.

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We determine, which of the points D, or E is calculated. Resistor/resistance of the loop between the points G and D

$$4{,}03 \times 0{,}08 = 0{,}323\ \Omega.$$

resistance of the loop between the points G and E

$$3 \times 0{,}13 = 0{,}39\ \Omega.$$

Calculated proves to be point E. Impedance of loop "phase - zero" between the points A and E comprises:

$$Z_{п} = 1{,}53(0{,}07 + 0{,}08) + 0{,}39 = 0{,}62\ \Omega.$$

Nominal phase voltage

$$U_{н}=220\ V.$$

We determine the value cf single-phase current with the short circuit at the outermost point E of net (according to the condition of an example one should accept $Z_{т}=0$):

$$I_{к}=\frac{220}{0,62}=355\ a.$$

We check satisfaction cf condition (7-5) for all three versions cf the protection of line.

Version 1. The permissible minimum multiplicity of current short circuit with respect tc the rated current by smelting the insert of safety device/fuse according tc Table 7-8 is equal to:

$$K_{31}=3.$$

Hence: 3•80=240 A<355 A.

Thus, the reliable action ct the shielding line safety devices/fuses is provided.

Version 2. The permissible multiplicity cf current short circuit with respect to the thermal element/cell of the combined release, which has the conversely depending on the current characteristic, is equal to:

$$K_{31}=3.$$

Hence relationship/ratic (7-5)

$$3\cdot100=300\ a<355\ A$$

is fulfilled and the required PUE degree of reliability of the action of shielding apparatus is provided.

Version 3. According to the data of plant the guaranteed accuracy of setting for the automatic switches of the type A 3124 composes +-15o/o. After taking as in accordance with the indication Table 7-8 safety factor equal to 1.1, we will obtain:

$$K_{31}=1{,}1\cdot1{,}15=1{,}27;$$
$$1{,}27\cdot600=760\ a>355\ A$$

The reliability of the action of automatic switch with the short circuit at point B is not provided.

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Example 7-2. In the system with dully grounded neutral with the voltage 380/220 V the line is shielded by safety devices/fuses with the fuse links to the rated current 100 A. Assuming/setting $Z_T=0$, to determine the maximum length of line at which will be provided reliable blowing with the single-phase short circuit at the end of the line for the following versions of the execution of the line:

1. Aerial line with the aluminum wires by section 3x50+1x25 mm².

2. Triple-core cable with aluminum cores with section 3x50 mm² in aluminum shell, utilized as ground wire.

3. Three-strand unarmoured cable with aluminum veins/strands by section 3x50 mm² with grounding busbar in the form of steel strip by section 50x4 mm.

Solution. On Table 7-8 we determine the minimally permissible multiplicity of current the short circuit:

$$K_{31}=3.$$

Smallest permissible value of single-phase current the short circuit

$$I_{в}=3\cdot100=300\ A$$

Taking into account that through the condition of example $Z_т=0$, we find through formula (7-1) the great permissible resistor/resistance "phase - zero" the line:

$$Z_в<\frac{220}{300}=0{,}733\ \Omega.$$

We determine the specific resistor/resistance to 1 km of loop "phase zero":

for version 1 on Table 7-3

$$z_в=2{,}03\ \Omega/km;$$

for version 2 on Table 7-5

$$z_в=1{,}03\ \Omega/km;$$

for version 3 on Table 7-6

$$z_{n} = 2{,}74\ \Omega/km.$$

The maximum permissible lengths of line will be equal to:

version 1

$$l < \frac{0{,}733}{2{,}03} = 0{,}36\ км;$$

version 2

$$l < \frac{0{,}733}{1{,}03} = 0{,}71\ км;$$

version 3

$$l < \frac{0{,}733}{2{,}74} = 0{,}267\ км.$$

The maximum length of line is provided by the use/application of a cable with the use of an aluminum shell as the grounding (zero) wire.

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Section Eight

SELECTION OF WIRES AND CABLES ON THE ECONOMIC CURRENT DENSITY.

The "rules of the device/equipment of electrical devices" established/installed economic current densities on which must be selected the sections of the wires of aerial lines and cores of cables.

Economic current density is determined from table 8-1.

The section of conductor according to the condition of economic current density is determined from the formula

$$F_{э} = \frac{I}{j_{э}}, \ мм^2, \qquad (8\text{-}1)$$

where I - calculated current of line, a;

$j_{э}$ - economic current density, A/mm^2, taken on tables 8-1.

The calculated current of line is accepted from the conditions for normal operation and during its determination is not considered an increase of the current in the line with the emergencies or the repairs in any elements/cells of net.

The obtained on (8-1) section of conductor is rounded off before the nearest standard section.

With the use Tables 8-1 it is necessary to be guided by the following:

1. With the maximum current load in the night time economic current density is raised by 40c/c.

2. For insulated wires by section 16 mm² and less economic current densities increase by 40o/c.

3. For lines with identical section of conductors all over length and different loads in individual sections their (Fig. 8-1) economic current density for initial section increases in comparison with values, indicated in Table 8-1, K_y once; in this case coefficient of increase is determined from formula

$$K_y = \sqrt{\frac{I_1^2 L}{I_1^2 l_1 + I_2^2 l_2 + \cdots + I_m^2 l_m}}, \qquad (8\text{-}2)$$

where $I_1, I_2, \ldots, I_m$ — current loads of individual sections of line;

$l_1, l_2, \ldots, l_m$ — length of the same sections of line;

L - overall length of line.

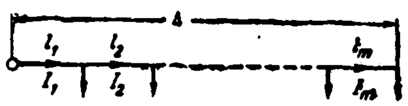

Fig. 8-1. Schematic of line with different current loads of sections.

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Table 8-1. Maximum economic current density, A/mm².

Наименования проводников (1)	Продолжительность использования максимума нагрузки, ч (2)		
	1 000—3 000	3 000—5 000	более 5 000 (3)
Голые провода и шины: (4)			
медные (5)	2,5	2,1	1,8
алюминиевые (6)	1,3	1,1	1,0
Кабеля с бумажной и провода с резиновой изоляцией с жилами: (7)			
медными (8)	3,0	2,5	2,0
алюминиевыми (9)	1,6	1,4	1,2
(10) Кабеля с резиновой и пластмассовой изоляцией с жилами:			
медными (8)	3,5	3,1	2,7
алюминиевыми (9)	1,9	1,7	1,6

Key: (1). Designations of conductors. (2). Demand time of load peak, h. (3). it is more. (4). Bare wires and busbars. (5). copper. (6). aluminum. (7). Cables from paper and wire with rubber insulation with veins/strands. (8). copper. (9). aluminum. (10). Cables with rubber and molded insulation with veins/strands.

Table 8-2. Average number of use of a peak load for different categories of users and branches of industry.

Потребители (1)	г. ч (2)
По категориям потребителей (3)	
Внутреннее освещение городов (4)	1 500—2 500
Наружное освещение городов (5)	2 000—3 600
Промышленные предприятия, работающие: (6)	
1) в одну смену (7)	2 000—3 000
2) в две смены (8)	3 000—4 500
3) в три смены (9)	4 500—7 000
По отраслям промышленности (10)	
Металлургическая (11)	6 500
Химическая (12)	6 200
Горнорудная (13)	6 000
Машиностроительная (14)	4 000
Бумажная (15)	5 500
Пищевая (16)	5 000
Полиграфическая (17)	3 000
Текстильная (18)	4 500
Обувная (19)	3 000
Деревообрабатывающая (20)	2 500
Холодильная (21)	4 000

Key: (1). Users. (2). h. (3). On categories of users. (4). Interior lighting of cities. (5). Exterior lighting of cities. (6). Industrial enterprises, which work. (7). in one exchange. (8). in two exchanges. (9). in three exchanges. (10). On branches of industry. (11). Metallurgical. (12). Chemical. (13). Mining. (14). Machine-building. (15). Paper. (16). Food. (17). polygraphic. (18). Textile. (19). Shoe. (20). Woodworking. (21). Cooling.

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Table 8-3. Economic currents for the uninsulated wires and cables, A.

Марки и сечения проводов и кабелей (1)	Экономический ток, а, при числе часов использования максимума в год (2)		
	более 5 000 (3)	3 000—5 000	(4) менее 3 000
	Неизолированные провода (5)		
А-16	16	18	21
А-25	25	27	32
А-35	35	38	45
А-50	50	55	65
А-70	70	77	91
А-95	95	104	123
А-120	120	132	156
А-150	150	165	195
М-6	11	13	15
М-10	18	21	25
М-16	29	34	40
М-25	45	53	63
М-35	63	73	87
М-50	90	104	125
М-70	126	146	174
М-95	170	199	237
М-120	216	252	300
М-150	271	316	376
	Трехжильные кабели с бумажной изоляцией (6) *С медными жилами*		
3×10	20	25	30
3×16	32	40	48
3×25	50	62	75
3×35	70	87	105
3×50	100	125	150
3×70	140	175	210
3×95	190	237	285
3×120	240	300	360
3×150	300	375	450
3×185	370	465	—
	С алюминиевыми жилами (7)		
3×10	12	14	16
3×16	19	22	26
3×25	30	35	40
3×35	42	49	56
3×50	60	70	80
3×70	84	98	112
3×95	113	132	151
3×120	144	168	192
3×150	180	210	240
3×185	222	260	296

Key: (1). Brands and the section of wires and cables. (2). Economic current, a, with total hours of utilization of maximum per annum. (3). it is more. (4). it is less. (5). uninsulated wires. (6). Triple-cores cable with paper insulation with copper veins/strands. (7). With aluminum veins/strands.

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4. When selecting of sections of conductors for feed of series/row of uniform mutually reserved electrical receivers (for example, pumps of water supply, conversion units, etc.) by total number n, if it is known that they all are not simultaneously switched on and by n_1 of them alternately are located in work, economic density must be increased against norms table 8-1 by multiplication by coefficient

$$K_{n_1}=\sqrt{\frac{n}{n_1}}. \quad (8\text{-}3)$$

The advisability of an increase in the number of lines or circuits over necessary in reliability conditions of power supply, and also replacing the existing heavy guage wires with an increase in the load for the purpose of the satisfaction of the conditions of economic current density must be based only on the basis of the technical-economic calculations the procedure of fulfillment of which is given in Section 10.

To testing on the econcmic current density they are not subject:

1) to the net of industrial enterprises and installaticns by voltage to 1000 into with the total hours of utilization a load peak of enterprise to 4000-5000;

2) all branchings to the separate electrical receivers by voltage of up to 1000 V, or lighting systems in the industrial enterprises, in the habitable and public buildings, the checked for the loss voltages;

3) the net of temporary/time installations, or of devices/equipment with the short service life (3-5 years);

4) the collecting mains;

5) the conductors, that go to resistances, starting rheostats, etc.

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For the definition of average total hours of utilization a load

peak in the absence of specified data it is possible to use given in Table 8-2 tentative data both on categories of users and on different fundamental branches of industry.

Table 8-3 gives the values or the current in the line, which ensures the greatest efficiency/cost-effectiveness of operation in depending on material and section of wires and cores of cables and annual total hours of utilization of a peak load.

Example to 8-1. Is required to select on the economic current density the section of cable 6 kV with the paper insulation and the aluminum veins/strands for the feed of woodworking plant with the maximum current load 54A.

Solution. Through tables 8-2 we find average total hours of utilization a load peak for the woodworking industry: T=2500 h.

In the graph/count table 8-3, that corresponds to total hours of utilization are less than 3000 for the cables with the paper insulation and the aluminum veins/strands, we determine that the economic current density will be provided with the cable with section 3x35 mm².

Example 8-2. Fig. 8-2 depicts the schematic of aerial line of

urban electric system 380/220 in, performed by aluminum wires with the identical section all over length of line.

It is necessary to select the section of wires, which corresponds to economic current density, with the total hours of utilization of a maximum are less than 3000.

Solution. We determine the coefficient of an increase in the economic current density for the initial section in (8-4):

$$K_y = \sqrt{\frac{98^2(0,08+0,04+0,1+0,08)}{98^2\cdot 0,08+52^2\cdot 0,04+26^2\cdot 0,1+15^2\cdot 0,08}} = 1,72.$$

Economic current density for the line with the identical load all over length we determine on table 8-1 with the total hours of utilization of a maximum less than 3000 for the aluminum bare wires: 1.3 A/mm².

For the conditions of an example economic current density taking into account the load distribution along the line is equal to:

$$j_e = 1,72\times 1,3 = 2,24\ A/mm^2.$$

The economic section of line we determine from (8-1):

$$F_e = \frac{98}{2,24} = 43,7\ mm^2.$$

We stop for the wires of line in the nearest standard section 50 mm². The section accepted must be checked according to the conditions of heating and loss of voltage.

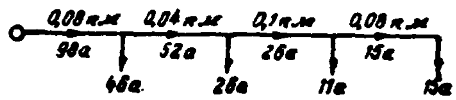

Fig. 8-2. Schematic of line for example 8-2.

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Example 8-3. To select on the economic current density the section of cables with the paper insulation and the aluminum veins/strands on 6 kV, the feeding electric motors pumps. In all pumping units three, from which two are worker, and one - stand-by. Calculated current of each cable 65A; total hours of utilization of a maximum of the electric motors of working pumps 4000.

Solution. Economic current density without taking into account the coefficient of an increase for the conditions of an example we determine on tables 8-1: 1.4 A/mm². The coefficient of an increase, which considers a number of working and stand-by lines, we find from (8-3). In our case of $n=3$ and $n_1=2$, and the coefficient of an increase is equal to:

$$K_{y1} = \sqrt{\frac{3}{2}} = 1,22.$$

Economic current density taking into account the mode of operation of pumping units comprises $j_э = 1.22 \cdot 1.4 = 1.72$.

Economic section of the cable

$$F_э = \frac{65}{1.72} = 37.8 \text{ мм}^2.$$

We accept for the cables near standard section 35 mm².

section Nine

POWER LOSSES AND ELECTRIC POWER IN ELECTRICAL NETWORKS.

The losses of active power in the section of electrical network, made by the wires of identical section, are determined from to the formula

$$\Delta P = a_3 N r = a_3 (N_a + N_r) r, \text{ квт.}^{(1)} \qquad (9\text{-}1)$$

by Key: (1). kW.

The losses of reactive power in the section of electrical network with identical inductive reactance of line are determined from the formula

$$\Delta Q = a_3 N x = a_3 (N_a + N_r) x, \text{ квар.} \qquad (9\text{-}2)$$

Key: (1). kilovar.

where N_a — sum of the products of the squares of resistive loads on the lengths of the sections of net with these loads;

N_r — sum of the products of the squares of reactive load on the lengths of the sections of net with these loads;

N - sum of the products of the squares of full loads on the lengths of the sections of net with these loads;

r and x - active and inductive reactances of line, Ω/km;

a_0— coefficient, depending on the system of the current and the units accepted measurement.

The values of entering formulas (9-1) and (9-2) value N_a, N_r and N, coefficient a_0 and units their measurement are given in Table 9-1.

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Power losses in the transformer are determined from the formulas:

the loss of the active power

$$\Delta P_T = \Delta P_0 + \Delta P_{\kappa.з}\beta^2, \text{ квт}; \qquad (9\text{-}3)$$

Key: (1). kW.

the loss of the reactive power

$$\Delta Q_T = \frac{S_n}{100}(I_{x.x} + U_x\beta^2),\ \text{квар.}^{(1)} \qquad (9\text{-}4)$$

Key: (1). kilovar.

where ΔP_0 — no-load loss of transformer (loss in steel), kW;

$\Delta P_{k.s}$ — loss the short circuit of transformer (coil loss) with nominal load, kW;

$I_{x.x}$ — running-light current of transformer, o/o;

U_x — voltage drop in the reactance of transformer, o/o;

S_n — nominal power of transformer, kVA;

β - load factor of the transformer;

$$\beta = \frac{S}{S_n}, \qquad (9\text{-}5)$$

where S - actual load of transformer, kVA.

Formula (9-4) for determining the losses of reactive power in the transformer can be represented in the form:

$$\Delta Q_T = \Delta Q_{x.x} + \Delta Q_n\beta^2,\ \text{квар.}^{(1)} \qquad (9\text{-}6)$$

Key: (1). kilovar.

where $\Delta Q_{x.x}$ — loss of reactive power in transformer with the idling (loss to the magnetization), the kilovar:

$$\Delta Q_{x.x}=\frac{S_{н}I_{x.x}}{100},\ \overset{(1)}{квар};$$

Key: (1). kilovar

$\Delta Q_{н}$ — the loss of reactive dissipated power in transformer with the nominal load, the kilovar:

$$\Delta Q_{н}=\frac{S_{н}U_{x}}{100},\ \overset{(1)}{квар}.$$

Key: (1). kilovar.

A voltage drop in the reactance of transformer is presented according to the formula

$$U_{x}=\sqrt{U_{к}^{2}-U_{r}^{2}},\ \%. \qquad (9\text{-}7)$$

where $U_{к}$ — voltage short circuit of transformer, o/o;

- U_{r} — drop of transformer, determined from the expression

$$U_{r}=\frac{\Delta P_{к.з}}{S_{н}}\cdot 100,\ \%. \qquad (9\text{-}8)$$

For the transformers with a power ≥10 of MVA it is possible to

accept $U_x \approx U_n$.

Values ΔP_c, $\Delta P_{к.з.}$, $\Delta Q_{х.х}$ and $\Delta Q_к$ for the step-down transformers are given in Table 9-2-9-6. In Tables 9-2, 9-3, 9-5 and 9-6 level B of the losses of active idle power relates to the transformers in which is used transformer steel with the thickness of 0.35 mm of brand E of 330 A according to GOST 80-256 with the refractory coating and the annealing of plates. Table 9-2-9.4 gives the values of active and reactive/jet resistances of transformers, the given with respect to the nominal voltage windings VN.

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Table 9-1. Values and units are the measurement of the values, entering formulas (9-1) and (9-2).

Система тока (1)	Сумма произведений квадратов нагрузок на длины участков линии (2)						n_0	Единица измерения (3)
	N_a	Единица измерения (3)	N_r	Единица измерения (3)	N	Единица измерения (3)		
Трехфазный (4) переменный (5)	$\Sigma I_a^2 l$	$a^2\cdot км$ (6)	$\Sigma I_r^2 l$	$a^2\cdot км$ (6)	$\Sigma I^2 l$	$a^2\cdot км$ (6)	$3\cdot10^{-3}$	—
	$\Sigma P^2 l$	$квт^2\cdot км$ (7)	$\Sigma Q^2 l$	$квар^2\cdot км$ (8)	$\Sigma S^2 l$	$ква^2\cdot км$ (9)	$\frac{1\cdot10^{-3}}{U_н^2}$	$кв^{-2}$ (10)
	$\Sigma P^2 l$	$Мвт^2\cdot км$ (11)	$\Sigma Q^2 l$	$Мвар^2\cdot км$ (12)	$\Sigma S^2 l$	$Мва^2\cdot км$ (13)	$\frac{10^3}{U_н^2}$	$кв^{-2}$ (10)
Однофазный переменный (14)	$\Sigma I_a^2 l$	$a^2\cdot км$ (6)	$\Sigma I_r^2 l$	$a^2\cdot км$ (6)	$\Sigma I^2 l$	$a^2\cdot км$ (6)	$2\cdot10^{-3}$	—
	$\Sigma P^2 l$	$квт^2\cdot км$ (7)	$\Sigma Q^2 l$	$квар^2\cdot км$ (8)	$\Sigma S^2 l$	$ква^2\cdot км$ (9)	$\frac{2\cdot10^{-3}}{U_н^2}$	$кв^{-2}$ (10)
Постоянный (15)	$\Sigma I^2 l$	$a^2\cdot км$ (6)	0	—	—	—	$2\cdot10^{-3}$	
	$\Sigma P^2 l$	квт км (7)	0	—	—	—	$\frac{2\cdot10^{-3}}{U_н^2}$	$кв^{-2}$ (10)

Key: (1). System of current. (2). Sum of products of the squares of loads on lengths of sections of line. (3). Unit measurement. (4). Three-phase. (5). variable/alternating. (6). km. (7). kW²•km. (8). kvar²•km. (9). kVA²•km. (10). kV⁻². (11). MW²•km. (12). Mvar²•km. (13). MVA²•. (14). Single-phase variable/alternating. (15) Direct.

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Table 9-2. Technical data of the three-phase two-phase double wound power tank transformers of general/common/total sizing with a of 25-630 kVA to the voltage to 35 kV (GOST 12022-66).

Номинальная мощность, ква (1)	Верхний предел номинального напряжения обмотки, кв (2)	Схема и группа соединений обмоток (3)	Потери активной мощности, квт (4): холостого хода (5), уровень А (6)	Потери активной мощности, квт (4): холостого хода (5), уровень Б (6)	Потери активной мощности, квт: к.з. (7)	Напряжение к.з., % (8)	Ток холостого хода, % (9)	Сопротивления обмоток трансформатора, ом (10): активное (11)	Сопротивления обмоток трансформатора, ом (10): реактивное (12)	Потери реактивной мощности, квар (13): холостого хода (14)	Потери реактивной мощности, квар (13): к. з. (7)
25	10	У/Ун—0	0,105	0,125	0,6	4,5	3,2	96,0	152	0,80	0,95
	10	У/Zн—11	0,105	0,125	0,69	4,7	3,2	110	152	0,80	0,95
40	10	У/Ун—0	0,15	0,18	0,88	4,5	3,0	55,0	98,1	1,20	1,57
	10	У/Zн—11	0,15	0,18	1,0	4,7	3,0	62,5	99,5	1,20	1,59
63	10	У/Ун—0	0,22	0,265	1,28	4,5	2,8	32,3	63,7	1,76	2,53
	10	У/Zн—11	0,22	0,265	1,47	4,7	2,8	37,0	64,8	1,76	2,57
	20	У/Ун—0	0,245	0,29	1,28	5,0	2,8	129	290	1,76	2,88
	20	У/Zн—11	0,245	0,29	1,47	5,3	2,8	148	302	1,76	3,00
100	10	У/Ун—0	0,31	0,365	1,97	4,5	2,6	19,7	40,5	2,60	4,05
	10	У/Zн—11	0,31	0,365	2,27	4,7	2,6	22,7	41,2	2,60	4,12
	35	У/Ун—0	0,39	0,465	1,97	6,5	2,6	241	759	2,60	6,19
	35	У/Zн—11	0,39	0,465	2,27	6,8	2,6	278	785	2,60	6,41
160	10	У/Ун—0	0,46	0,54	2,65	4,5	2,4	10,4	26,2	3,84	6,69
	10	У/Д—11	0,46	0,54	2,65	4,5	2,4	10,4	26,2	3,84	6,69
	10	У/Zн—11	0,46	0,54	3,1	4,7	2,4	12,1	26,8	3,84	6,85
	35	У/Ун—0	0,56	0,66	2,65	6,5	2,4	127	481	3,84	10,1
	35	У/Д—11	0,56	0,66	2,65	6,5	2,4	127	481	3,84	10,1
	35	У/Zн—11	0,56	0,66	3,1	6,8	2,4	148	499	3,84	10,4
250	10	У/Ун—0	0,66	0,78	3,7	4,5	2,3	5,92	17,0	7,25	10,6
	10	У/Д—11	0,66	0,78	3,7	4,5	2,3	5,92	17,0	5,75	10,6
	10	У/Zн—11	0,66	0,78	4,2	4,7	2,3	6,72	17,6	5,75	11,0
	35	У/Ун—0	0,82	0,96	3,7	6,5	2,3	72,5	310	5,75	15,8
	35	У/Д—11	0,82	0,96	3,7	6,5	2,3	72,5	310	5,75	15,8
	35	У/Zн—11	0,82	0,96	4,2	6,8	2,3	82,3	322	5,75	16,5
400	10	У/Ун—0	0,62	1,08	5,5	4,5	2,1	3,44	10,7	8,40	17,1
	10	Ун/Д—11	0,92	1,08	5,5	4,5	2,1	3,44	10,7	8,40	17,1
	10	Д/Ун—11	0,92	1,08	5,9	4,5	2,1	3,69	10,6	8,40	17,0
	35	У/Ун—0	1,15	1,35	5,5	6,5	2,1	42,1	195	8,40	25,4
	35	У/Д—11	1,15	1,35	5,5	6,5	2,1	42,1	195	8,40	25,4
630	10	У/Ун—0	1,42	1,68	7,6	5,5	2,0	1,91	8,52	12,6	33,8
	10	Ун/Д—11	1,42	1,68	7,6	5,5	2,0	1,91	8,52	12,6	33,8
	10	Д/Ун—11	1,42	1,68	8,5	5,5	2,0	2,14	8,46	12,6	33,6
	10	У/Ун—0	1,42	1,68	8,5	5,5	2,0	2,14	8,46	12,6	33,6
	35	У/Ун—0	1,7	2,0	7,6	6,5	2,0	23,5	124	12,6	40,2
	35	У/Д—11	1,7	2,0	7,6	6,5	2,0	23,5	124	12,6	40,2

Note. The conventional designations of the connections of windings (GOST 11677-65): U - star; Ун - star with the derived zero point; Zн - zigzag with the derived point; D - triangle.

Key: (1). Nominal power, kVA. (2). Upper limit of nominal voltage of winding, kV. (3). Diagram and group of connections of windings. (4). Losses of active power, kW. (5). idling. (6). level. (7). short circuit. (8). Voltage short circuit o/o. (9). Running-light current. o/o. (10). Winding impedances transformer, ohm. (11). active. (12). reactive/jet. (13). Losses of reactive power, kilovar. (14). idling.

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Table 9-3. Technical specifications of the three-phase double wound power tank transformers of general/common/total sizing with a of 1-80 MVA to the voltage to 35 kV (GOST 11920-66).

Тип трансформатора (1)	Номинальная мощность, Мва (2)	Верхний предел номинальных напряжений обмоток, кв (3)		Потери активной мощности, квт (4)			Напряжение к.з., % (8)	Ток холостого хода, % (9)	Сопротивления обмоток трансформатора, ом (10)		Потери реактивной мощности, квар (11)	
		ВН	НН	холостого хода (5) уровень А (6)	холостого хода (5) уровень Б (6)	к. з. (7)			активное (12)	реактивное (13)	холостого хода (14)	к. з. (15)
ТМ	1,0	10	0,69	2,1	2,45	12,2	5,5	1,4	1,22	5,36	14,0	53,6
		10	10,5	2,1	2,45	11,6	5,5	1,4	1,16	5,38	14,0	53,8
		35	0,69	2,35	2,75	12,2	6,5	1,5	14,9	78,2	15,0	63,8
		35	10,5	2,35	2,75	11,6	6,5	1,5	14,2	78,3	15,0	64,0
	1,6	10	0,69	2,8	3,3	18,0	5,5	1,3	0,7	3,36	20,8	86,4
		10	6,3	2,8	3,3	16,5	5,5	1,3	0,64	3,38	20,8	86,4
		35	0,69	3,1	3,65	18,0	6,5	1,4	8,61	49,0	22,4	102
		35	10,5	3,1	3,65	16,5	6,5	1,4	7,90	49,1	22,4	103
	2,5	10	0,69	3,9	4,6	25,0	5,5	1,0	0,40	2,16	25,0	135
		10	10,5	3,9	4,6	23,5	5,5	1,0	0,38	2,17	25,0	135
		35	0,69	4,35	5,1	25,0	6,5	1,1	4,90	31,5	27,5	161
		35	10,5	4,35	5,1	23,5	6,5	1,1	4,61	31,5	27,5	161
	4,0	10	6,3	5,45	6,4	33,5	6,5	0,9	0,21	1,61	36,0	258
		35	10,5	5,7	6,7	33,5	7,5	1,0	2,56	22,8	40,0	298
	6,3	10	10,5	7,65	9,0	46,5	6,5	0,8	0,12	1,03	50,4	407
		35	10,5	8,0	9,4	46,5	7,5	0,9	1,44	14,5	56,7	470
ТНМ	1,0	10	0,69	2,1	2,45	12,2	5,5	1,4	1,22	5,36	14,0	53,6
		35	0,69	2,35	2,75	12,2	6,5	1,5	14,9	78,2	15,0	63,8
		35	11	2,35	2,75	11,6	6,5	1,5	14,2	78,3	15,0	64,0
	1,6	10	0,69	2,8	3,3	18,0	5,5	1,3	0,70	3,36	20,8	86,1
		10	6,3	2,8	3,3	16,5	5,5	1,3	0,64	3,38	20,8	86,4
		35	0,69	3,1	3,65	18,0	6,5	1,4	8,61	49,0	22,4	102
		35	11	3,1	3,65	16,5	6,5	1,4	7,90	49,1	22,4	103
	2,5	10	0,69	3,9	4,6	25,0	5,5	1,0	0,40	2,16	25,0	135
		10	6,3	3,9	4,6	23,5	5,6	1,0	0,38	2,17	25,0	135
		35	0,69	4,35	5,1	25,0	6,5	1,1	4,90	31,5	27,5	161
		35	11	4,35	5,1	23,5	6,5	1,1	4,61	31,5	27,5	161
	4,0	10	6,3	5,45	6,4	33,5	6,5	0,9	0,21	1,61	36,0	258
		35	11	5,7	6,7	33,5	7,5	1,0	2,56	22,8	40,0	298
	6,3	10	6,3	7,65	9,0	46,5	6,5	0,8	0,12	1,03	50,4	407
		35	11	8,0	9,4	46,5	7,5	0,9	1,44	14,5	56,7	470

ТД	10 16 40	38,5 38,5 38,5	10,5 10,5 10,5	12,3 17,8 33,0	14,5 21,0 39,0	65,0 90,0 180	7,5 8 8,5	0,8 0,75 0,65	0,96 0,52 0,17	11,1 7,39 3,15	80,0 120 260	747 1 277 3 395
ТДЦ	80	38,5	10,5	55,0	65,0	330	9	0,6	0,08	1,67	480	7 192
ТДН	10 16 25	36,75 36,75 36,75	10,5 10,5 10,5	12,3 17,8 24,5	14,5 21,0 29,0	65 90 125	8 8 8	0,8 0,75 0,7	0,88 0,47 0,27	10,8 6,73 4,31	80,0 120 175	797 1 277 1 996
ТМ	1,0	6,3	0,525	2,3	2,75	12,2	8	1,5	0,48	3,14	15,0	79,1
ТМН	6,3	10	3,15	8,0	9,4	46,5	8	0,9	0,12	1,26	56,7	502
ТДНС	10	36,75	6,3	12,3	14,5	85	14	0,8	1,14	18,8	80	1 600
ТДНС	16	36,75	6,3	17,8	21,0	105	10	0,75	0,55	8,4	120	1 600
ТРДН	25	36,75	10,5	24,5	29,0	145	ВН—НН 9,5 $НН_1$—$НН_2$ не (16) менее 15	0,7	—	—	—	—
ТРДН	32	36,75	10,5	28,0	33,0	По техническим условиям (17)	ВН—НН 11,5 $НН_1$—$НН_2$ не (16) менее 20	0,7	—	—	—	—
	40	36,75	10,5	33,0	39,0	То же (18)	ВН—НН 18,5 $НН_1$—$НН_2$ (16) не менее 14	0,65	—	—	—	—
	63	36,75	10,5	48,0	55,0	280	ВН—НН 11,5 $НН_1$—$НН_2$ не (16) менее 20	0,6	—	—	—	—

Note. For the transformers with that increased by the values of voltages short circuits the latter are calibrated temporarily.

Key: (1). Type of transfcrmer. (2). Nominal pcwer, MVA. (3). Upper limit of nominal voltages oi wirdings, kV. (4). Losses of active power, kW. (5). idling. (6). level. (7). shcrt circuit. (8). Voltage short circuit, o/o. (9). Current cf idle code, c/o. (10). Winding impedances of transfcrmer, ohm. (11). Losses cf reactive power, kilovar. (12). active. (13). reactive/jet. (14). idling. (15). short circuit. (16). not less. (17). Acccrding to technical specifications. (18). Then.

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Table 9-4. Technical specifications of the three-phase double wound power tank transformers of general/common/total sizing in to 31.5 kVA to the voltage to 110 kV (GOST 401-41).

Номинальная мощность, Мва (1)	Верхний предел номинального напряжения обмоток, кв (2)		Потери, квт (3)		Потеря напряжения при номинальной нагрузке и cosφ=1, % (6)	Напряжение к. з., % (7)	Ток холостого хода, % (8)	Сопротивления обмоток трансформатора, ом (9)		(12) Потери реактивной мощности, квар	
	ВН	НН	холостого хода (4)	к. з. (5)				активное (10)	реактивное (11)	холостого хода (13)	(14) к. з.
0.005	6.3	0,4	0,06	0.185	3.8	5.5	10	294	323	0.50	0.20
0.01	6.3	0.4	0.105	0.335	3.45	5.5	10	133.0	173	1.00	0.44
	10	0.4	0.140	0.335	3.45	5.5	10	335	436	1.00	0.44
0.02	6.3	0.4	0.18	0.6	3.1	5.5	9	59.5	91.5	1.80	0.92
	10	0.4	0.22	0.6	3.1	5.5	10	150	230	2.00	0.92
0.03	6.3	0.4	0.25	0.85	2.95	5.5	8	37.5	62.4	2.40	1.41
	10	0.4	0.3	0.85	2.95	5.5	9	94.4	157	2.70	1.41
0.05	6.3	0.525	0.35	1.325	2.75	5.5	7	21.0	38.3	3.50	2.41
	10	0.4	0.44	1.325	2.75	5.5	8	53.0	96.4	4.00	2.41
	35	0.4	0.54	1.325	2.85	6.5	9	649	1 454	4.50	2.97
0.75	6.3	0.525	0.49	1.875	2.6	5.5	6.5	13.0	2.91	4.88	4.12
	10	0.4	0.59	1.875	2.6	5.5	7.5	33.0	7.33	5.63	4.12
0.1	6.3	0.525	0.6	2.4	2.5	5.5	6.5	9.53	19.6	6.50	4.95
	10	0.525	0.73	2.4	2.5	5.5	7.5	24.0	49.5	7.50	4.95
	35	0.525	0.9	2.4	2.6	6.5	8	294	740	8.00	6.04
0.135	6.3	0.525	0.83	3.07	2.4	5.5	6.5	6.69	14.7	8.78	6.76
	10	0.525	1.0	3.15	2.46	5.5	7.5	17.3	36.9	10.2	6.72
0.18	6.3	0.525	1.0	4.0	2.35	5.5	6	4.90	11.1	10.8	9.06
	10	0.525	1.2	4.1	2.4	5.5	7	12.7	27.8	12.6	9.01
	10	3.15	1.5	4.1	2.4	5.5	8	12.7	27.8	14.4	9.01
	35	10.5	1.5	4.1	2.45	6.5	8	155	414	14.4	11.0
0.24	6.3	0.525	1.4	4.9	2.17	5.5	6	3.38	8.45	14.4	13.3
	10	0.525	1.6	5.1	2.25	5.5	7	8.85	21.1	16.8	12.2
0.32	6.3	0.525	1.6	6.07	2.05	5.5	6	2.35	6.40	19.2	16.5
	10	0.525	1.9	6.2	2.05	5.5	7	6.05	16.1	22.4	16.5
	10	3.15	2.3	6.2	2.05	5.5	7.5	6.05	16.1	24.0	16.5
	35	10.5	2.3	6.2	2.15	6.5	7.5	74.1	238	24.0	19.9
0.42	10	0.525	2.1	7.7	1.96	5.5	6.5	4.37	12.4	27.3	21.8
0.56	10	0.525	2.5	9.4	1.8	5.5	6	3.00	9.35	33.6	29.3
	10	6.3	3.35	9.4	1.8	5.5	6.5	3.00	9.35	36.4	29.3
	35	10.5	3.35	9.4	1.85	6.5	6.5	36.7	137	36.4	35.2

0,75	10	0,525	4,1	11,9	1,73	5,5	6	2,12	7,02	45,0	39,5
1,0	10 35	6,3 10,5	4,9 5,1	15,0 15,0	1,64 1,7	5,5 6,5	5 5,5	1,50 18,4	5,29 77,5	50,0 55,0	52,9 63,2
1,35	10 35	6,3 10,5	6,0 6,5	19,5 19,5	1,59 1,65	5,5 6,5	5 5,5	1,07 13,1	3,93 57,5	67,5 74,3	71,6 85,6
1,8	10 35	6,3 10,5	8,0 8,3	24,0 24,0	1,47 1,53	5,5 6,5	4,5 5	0,74 9,07	2,96 43,3	81,0 90,0	96,0 115
2,4	10 35	6,3 10,5	9,2 10,0	31,5 31,5	1,45 1,51	5,5 6,5	4,5 5	0,55 6,70	2,23 32,5	108 120	128 153
3,2	10 38,5 121	6,3 10,5 38,5	11,0 11,5 16,6	37,0 37,0 39,5	1,3 1,4 1,78	5,5 7 10,5	4 4,5 4,5	0,36 5,36 56,5	1,68 32,0 447	128 144 144	172 221 334
4,2	10 35	6,3 10,5	14,0 14,5	47 47	1,27 1,4	5,5 7	4 4,5	0,27 3,26	1,28 20,2	168 189	226 290
5,6	10 38,5 121	6,3 10,5 38,5	18,0 18,5 25,5	56 57 62,5	1,11 1,3 1,67	5,5 7,5 10,5	4 4,5 4,5	0,18 2,69 29,2	0,97 19,7 273	224 252 252	303 416 385
7,5	38,5 121	11 38,5	24 33	75 77	1,25 1,58	7,5 10,5	3,5 4	1,98 20,0	14,7 204	253 300	557 784
10	38,5 121	11 38,5	29 38,5	92 97,5	1,2 1,53	7,5 10,5	3 3,5	1,36 14,3	11,0 153	300 350	744 1 046
15	38,5 121	11 38,5	39 50	122 133	1,1 1,44	8 10,5	3 3,5	0,80 8,65	7,86 102	450 525	1 194 1 569
20	38,5 121	11 38,5	48 60	148 163	1,0 1,37	8 10,5	2,5 3	0,55 5,97	5,90 76,6	500 600	1 593 2 094
31,5	38,5 121	11 38,5	73 86	180 200	0,9 1,19	8 10,5	2,2 2,7	0,27 2,95	3,75 48,7	693 851	2 514 3 301

Key: (1). Nominal power, MVA. (2). Upper limit cf ncminal voltage of windings, kV. (3). Losses, kW. (4). idling. (5). shcrt circuit. (6). Loss of voltage with ncminal lcad and ccsϕ=1, c/c. (7). Voltage short circuit, o/o. (8). Running-light current, o/o. (9). Winding impedances of transfcrmer, ohm. (10). active. (11). reactive/jet. (12). Losses of reactive pcwer, kilcvar. (13). idling. (14). short circuit.

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Table 9-5. Technical specifications of the three-phase double wound tank transformers of general/common/total sizing with a of 2.5-80 MVA to the voltage to 110 kV with ПБВ (GOST 12965-67).

Тип трансформатора (1)	Номинальная мощность, Мва (2)	Сочетание напряжений обмоток, кв (3)		Потери, квт (4)			Напряжение к. з., % (8)	Ток холостого хода, % (9)
				холостого хода (5)		(7)		
		ВН	НН	уровень А (6)	уровень Б (6)	к. з.		
ТМН	2,5	110	6,6; 11; 22	5	6,5	22	10,5	1,5
	6,3	115	6,6; 11; 22; 38,5	10	13	50	10,5	1,0
ТДН	10	115	6,6; 11; 22; 38,5	14	18	60	10,5	0,9
	16	115	6,6; 11; 22; 38,5	21	26	85	10,5	0,85
ТРДН	25	115	6,3/6,3; 10,5/10,5; 6,3/10,5; 22, 38,5	29	36	120	10,5	0,8
	32	115	6,3/6,3; 10,5/10,5 6,3/10,5; 22, 38,5	35	44	145	10,5	0,75
	40	115	6,3/6,3; 10,5/10,5; 6,3/10,5; 22; 38,5	42	52	175	10,5	0,7
ТРДЦН	63	115	6,3/6,3; 10,5/10,5; 6,3/10,5; 22; 38,5	59	73	260	10,5	0,65
	80	115	6,3/6,3; 10,5/10,5; 6,3/10,5; 22; 38,5	70	89	315	10,5	0,6

Note. Transformers with split windings have the power: VN - 100o/o, HH$_1$ and HH$_2$ - on 50o/o.

Key: (1). Type of transformer. (2). Nominal power, MVA. (3).

Combination of voltages cf windings, kV. (4). Lcssas, kW. (5). idling. (6). level. (7). short circuit. (8). Vcltage short circuit, c/o. (9). Running-light current, o/o.

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Table 9-6. Technical specifications of the three-phase triple-wound tank transformers of general/common/total sizing with a of 6.3-80 MVA to the voltage to 110 kV with БББ (GOST 12965-67).

Тип трансформатора (1)	Номинальная мощность, Мва (2)	Сочетание напряжений обмоток, кв (3)			Потери, квт (4)			Ток холостого хода, % (8)
					холостого хода (5)			
		ВН	СН	НН	уровень А (6)	уровень Б (6)	к. з. (7)	
ТМТН	6,3	115	22; 38,5	6,6; 11	14	17	60	1,2
ТДТН	10 16	115 115	22; 38,5 22; 38,5	6,6; 11 6,6; 11	19 26	23 32	80 105	1,1 1,05
ТДТН	25	115	11 22; 38,5	6,6 6,6; 11	36	45	145	1,0
	40	115	11 22; 38,5	6,6 6,6; 11	50	63	230	0,9
	63	115	38,5	6,6; 11	70	87	310	0,85
ТДЦТ	80	115	38,5	6,6; 11	82	102	390	0,8

Note. 1. Each winding is designed for complete nominal power of transformer.

2. Voltages short circuit between windings: VN SN 10.5o/o, VN-NN

- 17o/o and SN NN -6o/o. For transformers with a power of 16, 40 and MVA the voltages short circuit can comprise: VN SN 17o/o VP NN - 10.5o/o and SN NN - 6o/o.

Key: (1). Type of transformer. (2). Nominal power MVA. (3). Combination of voltages of windings, kV. (4). Losses, kW. (5). idling. (6). level. (7). short circuit. (8). Running-light current, o/o.

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For other nominal voltages of windings the resistors/resistances are recounted according to the formulas:

$$R' = \left(\frac{U'_{\text{н}}}{U_{\text{н}}}\right)^2 R, \text{ ом (1)};$$
$$X' = \left(\frac{U'_{\text{н}}}{U_{\text{н}}}\right)^2 X, \text{ ом (1)},$$

Key: (1). ohm.

where $U_{\text{н}}$ - nominal voltage of winding, indicated in Table 9-2-9-4, kV;

$U'_{\text{н}}$ - nominal voltage of winding, with respect to which are recounted resistors/resistances, kV;

R and X - respectively active and reactance of transformer, determined on Tables 9-2-9-4, ohms.

The losses of electric power in the net are determined from to the formula

$$\Delta A = \Delta P_б \tau, \text{ квт} \cdot \text{ч}^{(1)}, \quad (9\text{-}9)$$

Key: (1). kW•h.

where $\Delta P_б$ - greatest power losses in the net, kW;

τ - number of hours of maximum losses, determined in depending on the annual graph/curve of load.

The losses of electric power in the transformer are determined from to the formula

$$\Delta A = \Delta P_c t_т + \Delta P_{к.з} \beta^2 \tau, \text{ квт} \cdot \text{ч}^{(1)}, \quad (9\text{-}10)$$

Key: (1). kW•h.

where $t_т$ - number of hours of the work of transformer.

A number of hours of maximum losses, if is known the annual graph/curve of load, can be determined according to to the formula

$$\tau = \frac{\Sigma S^2 t}{S_б^2}, \text{ ч/год}^{(1)}, \quad (9\text{-}11)$$

Key: (1). h/year.

where $\Sigma S^2 t$ - sum of the products of the squares of full loads on the annual duration of each of them, calculated for entire annual graph/curve of the loads of the element/cell of the net in question;

S_{6} - greatest full load of the element/cell of net.

For the typical graph/curve, which has the lowered loads at night and morning and evening maximums, number of hours of the maximum losses according to data of institute Energoset'proyekt [All-Union State Planning, Surveying and Scientific Research Institute of Power Systems and Electric Power Networks] in depending on total hours of utilization of a maximum can be determined on Tables 9-7.

Example 9-1. To determine the annual losses of electric power in the transformer of the type TM with a power of 6.3 MVA with the voltage of the highest side 10 kV, if transformer is connected constantly and the annual graph/curve of its load is represented in Fig. 9-1.

Solution. The annual losses of electric power in the transformer we determine on (9-10).

Through Tables 9-3 we find the losses of active power in the transformer with the idling for the level B:

$$\Delta P_c = 9 \quad \text{kW}$$

and load losses (loss short circuit) with the nominal load of the transformer:

$$\Delta P_{к.з} = 46{,}5 \quad \text{kW}.$$

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According to the condition of an example an annual number of hours of the work of the transformer

$$t_т = 8\,760.$$

The load factor of transformer with the full load comprises:

$$\beta = \frac{4{,}5}{6{,}3} = 0{,}715.$$

A number of hours of maximum losses we determine from the graph/curve in Fig. 9-1, after substituting in (9-11) the values of the loads of transformer in megavolt--amperes and the corresponding to them operating times in thousands of hours:

$$\tau = \frac{4{,}5^2 \cdot 2{,}5 + 3{,}5^2 \cdot 3{,}5 + 1{,}5^2 \cdot 1{,}5 + 0{,}75^2 \cdot 1{,}26}{4{,}5^2} \cdot 10^3 = 4\,830 \text{ h}.$$

After substituting numerical values in (9-10), let us determine annual energy losses in the transformer:

$$A = 9 \cdot 8\,760 + 46{,}5 \cdot 0{,}715^2 \cdot 4\,830 = 183\,800 \text{ kW} \cdot \text{h}.$$

Example 9-2.

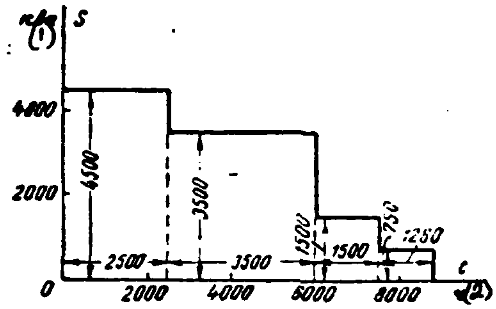

Fig. 9-1. Annual graph/curve of load for example 9-1.

Key: (1). kVA. (2). h.

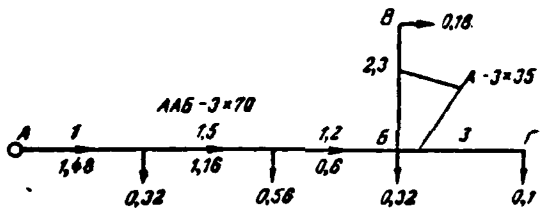

Fig. 9-2. Schematic of line for example 9-2.

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Fig. 9-2 depicts the schematic of line 6 kV with the indication of the lengths of the sections of line (km) and calculated (greatest) loads (MVA). Main line AB is made by cable with the aluminum veins/strands by section 3x70 mm², and branchings BV and BG - by aerial line with the aluminum wires by section 35 mm².

To determine the annual losses of electric power in the resistors/resistances of wires and cables of line, if the annual demand time of load peak is 3000 h and the graph/curve of loads is typical (are morning and evening maximums and dropping of load in the night time).

Solution. The greatest power losses in the resistors/resistances of wires and cables of the line we find through (9-1), in which the value of coefficient a_3 is determined from Table 9-1:

$$a_3 = \frac{10^3}{6^2} = 27.8.$$

The specific resistors/resistances of the sections of line we find through Tables 5-1: for the aluminum cable by section 70 mm² - 0.46 Ω/km; for the aluminum wire by section 35 mm² - 0.92 Ω/km.

We determine the value of value N for the main line AB:

$$N_{AB} = 1{,}48^2 \cdot 1 + 1{,}16^2 \cdot 1{,}5 + 0{,}6^2 \cdot 1{,}2 = 4{,}64 \text{ MVA}^2 \cdot \text{km};$$

for the branchings BV and BG

$$N_{Б(В+Г)} = 0{,}18^2 \cdot 2{,}3 + 0{,}1^2 \cdot 3 = 0{,}105 \text{ MVA}^2 \cdot \text{km}.$$

From (9.1) we find the greatest power losses in the net:

$$\Delta P_б = 27{,}8(4{,}64 \cdot 0{,}46 + 0{,}105 \cdot 0{,}92) = 86{,}2 \quad \text{кw.}$$

On Tables 9-7 in depending on the demand time of maximum T=3000 h we find the value of a number of hours of maximum losses τ=1300. The magnitude of losses of electric power we determine on (9-9):

$$\Delta A = 86{,}2 \cdot 1\,300 = 112\,000 \quad \text{кwh.}$$

Table 9-7. Number of hours of maximum losses.

(1) Число часов использования максимума	3 000	3 500	4 000	4 500	5 000
(2) Число часов максимальных потерь	1 300	1 650	2 000	2 500	3 000
(1) Число часов использования максимума	5 500	6 000	6 500	7 000	7 500
(2) Число часов максимальных потерь	3 650	4 300	5 000	5 700	6 450

Key: (1). Total hours of utilization of a maximum. (2). Number of hours of maximum losses.

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Section Ten

TECHNICAL-ECONOMIC CALCULATIONS.

Economic indices are decisive during the technical-economic evaluation/estimate of the versions of the execution of net.

When selecting of version must also be analyzed natural qualitative indices (energy losses, the expenditures of nonferrous metal, etc.), moreover in the case of the equivalence of versions in the relation to cost indices preference is given up to version with best qualitative indices.

The technical-economic evaluation/estimate of versions must be conducted in accordance with the "procedure of the technical-economic calculations in power engineering", affirmed by the resolution of the state Committee of the Council of Ministers of the USSR on science and technology on 12 October 1966. During the evaluation/estimate of comparative efficiency/cost-effectiveness of two or several versions for each of the compared versions must be determined the overall value of expenditures.

To most economical version corresponds the smallest value of the expenditures, determined according to to the formula

$$3 = p_н K + И, \text{ руб.} \, (1) \qquad (10\text{-}1)$$

Key: (1). rub.

where Z - an overall value of expenditures, rub;

I - annual expenses of operation, rub;

$p_н$ - standard coefficient of effectiveness which for all calculations in the field of power engineering they take as the equal to 15;

K - capital investments, rub.

In annual operating expenses I are included the depreciation allowance (expenditures for renovation and major overhaul), the cost/value of the losses of electrical energy in the net, the straight/direct pay of workers and employees, maintenance cost, deductions to the social insurance, the overhead expenses, etc.

Annual operating expenses for the electrical installation can be

determined according tc to the formula

$$И=(p_р+p_к+p_о)K+C_э, \text{ руб.}(1) \quad (10\text{-}2)$$

Key: (1). rub.

where $p_р$ - coefficient cf annual deductions tc the renovaticn of the installation (renovaticn - ccmplete restcraticn/reduction of installation after the discharge of the period cf its service);

$p_к$ - the same to the major cverhaul of the installation;

$p_о$ - the same to the straight/direct expenditures/consumpticns on maintenance/servicing and routine repair cf the installation;

$C_э$ - cost/value of the losses cr electrical energy, rub.

Taking into account (10-2) the expenditures can be represented the fcrmula

$$З=pK+C_э, \text{ руб.}(1) \quad (10\text{-}3)$$

Key: (1). rub.

where p - total annual deducticns from the fundamental insertions (capital expenditures):

$$p=p_н+p_р+p_к+p_о. \quad (10\text{-}4)$$

Depreciation allowance to the renovaticn tc the moment/tcrque cf their consumption according to the straight/direct destinaticn on this object can be used in cther sections cf raticnal economy.

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Table 10-1. Norms of depreciation allowance for the constructions of power transmission, power electrical equipment and distributors.

(1) Наименование сооружений	(2) Нормы амортизации, %	
	(3) на реновацию p'_p	(4) на капитальный ремонт p_k
(5) Воздушные линии электропередачи		
(6) 1. На металлических и железобетонных опорах		
(7) Напряжение:		
(8) до 22 кв (9)	2,5	1,0
35—160 кв (9)	2	0,8
220 кв и выше (10)	1,6	0,64
(11) 2. На опорах из пропитанной древесины с железобетонными приставками		
(7) Напряжение:		
(8) до 22 кв (9)	3,3	2,0
35—160 кв (9)	2,64	1,6
220 кв и выше (10)	2,11	1,28
(12) 3. На опорах из пропитанной древесины		
(7) Напряжение:		
(8) до 22 кв (9)	4,12	2,5
35—160 кв (9)	3,3	2,0
(13) 4. На опорах из непропитанной древесины		
(7) Напряжение:		
(8) до 22 кв (9)	5,15	3,13
35—160 кв (9)	4,12	2,5
(14) Кабельные линии		
(15) 1. Проложенные в земле и под водой		
(7) Напряжение:		
(8) до 10 кв (9)	2,5	0,5
35 кв (9)	3,13	1,0
50 кв и выше (10)	2,0	0,25
(16) 2. Проложенные в помещении		
(7) Напряжение:		
(8) до 10 кв (9)	2,0	0,4
35 кв (9)	2,5	0,8
(17) Силовое электротехническое оборудование и распределительные устройства	3,3	3,0
Электродвигатели		
(18) 1. Работа в одну смену		
(19) Мощность:		
(8) до 100 квт (20)	6,5	2,96
(21) свыше 100 квт (20)	3,8	2,88
(22) 2. Работа в две смены		
(19) Мощность:		
(8) до 100 квт (20)	6,5	3,7
(21) свыше 100 квт (20)	3,8	3,6

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(23) 3. Работа в три смены		
(19) Мощность:		
(8) до 100 *квт* (20)	6,5	4,44
(21) свыше 100 *квт* (20)	3,8	4,32
(24) **Электродвигатели при работе в агрессивной среде, при высокой температуре, в условиях повышенных влажности и загрязненности**		
(18) 1. Работа в одну смену		
(19) Мощность:		
(8) до 100 *квт* (20)	9,75	4,44
(21) свыше 100 *квт* (20)	5,7	4,32
(22) 2. Работа в две смены		
(19) Мощность:		
(8) до 100 *квт* (20)	9,75	5,55
(21) свыше 100 *квт* (20)	5,7	5,4
(23) 3. Работа в три смены		
(19) Мощность:		
(8) до 100 *квт* (20)	9,75	6,65
(21) свыше 100 *квт* (20)	5,7	6,48
(25) **Дизель-генераторы**		
(18) 1. Работа в одну смену		
(26) Скорость вращения:		
(8) до 500 *об/мин* (27)	3,3	2,8
500 *об/мин* и выше (28)	5,0	2,8
(22) 2. Работа в две смены		
(26) Скорость вращения:		
(8) до 500 *об/мин* (27)	3,3	3,5
500 *об/мин* и выше (28)	5,0	3,5
(23) 3. Работа в три смены		
(26) Скорость вращения:		
(8) до 500 *об/мин* (27)	3,3	4,2
500 *об/мин* и выше (28)	5,0	4,2
(29) **Регулирующие приборы и устройства** . . .	10	2

Key: (1). Designation cf constructions. (2). Ncrms of damping, o/o. (3). to renovation. (4). tc majcr cverhaul. (5). Air electric power lines. (6). On metallic and reinforced concrete suppcrts. (7). Voltage. (8). to. (9). kV. (10). kV are above. (11). On suppcrts from impregnated wood with reinforced concrete attachments. (12). On supports from impregnated wood. (13). On suppcrts from unimpregnated

wood. (14). Cable lines. (15). Laid in earth/ground and under water. (16). Laid in location. (17). Power electrical equipment and distributors electric motors. (18). Work in one exchange. (19). Power. (20). kW. (21). it is more than. (22). Work in two exchanges. (23). Work in three exchanges. (24). Electric motors with work in agressive medium, at high temperature, under conditions for those increased of humidity and pollution/contamination. (25). Diesel generators. (26). Rotational speed. (27). r/min. (28). r/min are above. (29). Control instruments and devices/equipment.

In connection with this the coefficient of deductions to the renovation should be determined from the formula

$$p_p = \frac{p_n}{(1+p_n)^{\frac{1}{p'_p}} - 1}, \qquad (10\text{-}5)$$

where p'_p - coefficient of deductions to the renovation, determined in accordance with the "Norms of depreciation allowance in the fixed capital for the national economy of the USSR", affirmed by the resolution of the Council of Ministers of the USSR of 1 September of 1961 (Table 10-1).

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Table 10-2. Yearly deductions from the fundamental capital investments, o/o.

(1) Наименование	(2) Нормативный коэффициент эффективности $P_н$	(3) Отчисления на амортизацию: (6) реновация $P_р$	Отчисления на амортизацию: (7) капитальный ремонт $P_к$	(4) Расходы на эксплуатацию и текущий ремонт $P_о$	(5) Всего P
(8) Воздушные линии электропередачи					
(9) 1. На металлических и железобетонных опорах					
(10) Напряжение:					
(11) до 22 *кв* (12)	15	0,06	1	2**	18,06
35—160 *кв* (12)	15	0,01	0,8	0,4 (1,0)* / 0,2 (0,7)	16,21 (16,81) / 16,01 (16,51)
220 *кв* и выше (13)	15	0	0,64	0,36 (0,76)* / 0,16 (0,46)	16 (16,4) / 15,8 (16,1)
(14) 2. На опорах из пропитанной древесины с железобетонными приставками					
(10) Напряжение:					
(11) до 22 *кв* (12)	15	0,22	2	3**	20,22
35—160 *кв* (12)	15	0,08	1,6	0,9 (1,4)*	17,58 (18,08)
220 *кв* и выше (13)	15	0,02	1,28	0,72 (0,92)*	17,02 (17,22)
(15) 3. На опорах из пропитанной древесины					
(10) Напряжение:					
(11) до 22 *кв* (12)	15	0,52	2,5	4**	22,02
35—160 *кв* (12)	15	0,22	2	4**	21,22
(16) 4. На опорах из непропитанной древесины					
(10) Напряжение:					
(11) до 22 *кв* (12)	15	1,06	3,13	4**	23,19
35—160 *кв* (12)	15	0,52	2,5	4**	22,02
(17) Кабельные линии					
(18) 1. Проложенные в земле и под водой					
(10) Напряжение:					
(11) до 10 *кв* (12)	15	0,06	0,5	2**	17,56
35 *кв* (12)	15	0,18	1,0	2*	18,18
80 *кв* и выше (13)	15	0,01	0,25	2*	17,26
(19) 2. Проложенные в помещении					
(10) Напряжение:					
(11) до 10 *кв* (12)	15	0,01	0,4	2**	17,41
35 *кв* (12)	15	0,06	0,8	2**	17,86
(20) Силовое электротехническое оборудование, распределительные устройства и подстанции					
(10) Напряжение:					
(11) до 20 *кв* (12)	15	0,22	3	4**	22,22
35—150 *кв* (12)	15	0,22	3	2*	20,22
220 *кв* и выше (13)	15	0,22	3	1*	19,22
(21) Электродвигатели					
(22) 1. Работа в одну смену					
(23) Мощность:					
(11) до 100 *квт* (24)	15	1,98	2,96	3,5***	23,44
(25) свыше 100 *квт* (24)	15	0,39	2,88	3***	21,27

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Continuation Table 10-2.

2. Работа в две смены					
Мощность:					
до 100 *квт*	15	1,98	3,7	4***	24,68
свыше 100 *квт*	15	0,39	3,6	3,5***	22,49
3. Работа в три смены					
Мощность:					
до 100 *квт*	15	1,98	4,44	5***	26,42
свыше 100 *квт*	15	0,39	4,32	4,5***	24,21
Электродвигатели при работе в агрессивной среде, при высокой температуре, в условиях повышенных влажности и загрязненности					
1. Работа в одну смену					
Мощность:					
до 100 *квт*	15	4,69	4,44	—	—
свыше 100 *квт*	15	1,41	4,32	—	—
2. Работа в две смены					
Мощность:					
до 100 *квт*	15	4,69	5,55	—	—
свыше 100 *квт*	15	1,41	5,4	—	—
3. Работа в три смены					
Мощность:					
до 100 *квт*	15	4,69	6,65	—	—
свыше 100 *квт*	15	1,41	6,48	—	—
Дизель-генераторы					
1. Работа в одну смену					
Скорость вращения:					
до 500 *об/мин*	15	0,22	2,8	—	—
500 *об/мин* и выше	15	0,97	2,8	—	—
2. Работа в две смены					
Скорость вращения:					
до 500 *об/мин*	15	0,22	3,5	—	—
500 *об/мин* и выше	15	0,97	3,5	—	—
3. Работа в три смены					
Скорость вращения:					
до 500 *об/мин*	15	0,22	4,2	—	—
500 *об/мин* и выше	15	0,97	4,2	—	—
Регулирующие приборы и устройства	15	4,92	2	3***	24,92

Key: (1). Designation. (2). Standard coefficient of effectiveness. (3). Depreciation allowances. (4). Expenditures for operation and routine repair. (5). In all. (6). renovation. (7). major overhaul.

(8). Air electric power lines. (9). On metallic and reinforced concrete supports. (10). Voltage. (11). to. (12). kV. (13). kV are above. (14). On supports from impregnated wood with reinforced concrete attachments. (15). On supports from impregnated wood. (16). On supports from unimpregnated wood. (17). Cable lines. (18). laid in earth/ground and under water. (19). Laid in location. (20). Power electrical equipment, distributors and substations. (21). Electric motors. (22). Work in one exchange. (23). Power. (24). kW. (25). it is more than. (26). Work in two exchanges. (27). Work in three exchanges. (28). Electric motors with work in aggressive medium, at high temperature, under conditions for those increased of humidity and pollution/contamination. (29). Diesel generators. (30). Rotational speed. (31). r/min. (32). r/min are above. (33). Control instruments and devices/equipment.

Notes: 1. Depreciation allowances are given in accordance with "The norms of depreciation allowance on the fixed capital for the national economy of the USSR", affirmed by the resolution of the Council of Ministers of the USSR from 1 September 1961 No 802 (they are put into operation from 1 January 1963).

2. Values of deductions for renovation are determined in accordance with "Procedure of technical-economic calculations in power engineering, affirmed by resolution GK of Council of Ministers

of USSR for science and technology on 12 October 1966.

FOOTNOTE [1]. Values of deductions for maintenance/servicing and routine repair according to the data of VGPI Energoset'proyekt. For the metallic and reinforced concrete supports in the numerator are shown the values of the deductions for single-circuit, in the denominator - for the twin-circuit supports. In the brackets are given the corresponding values for the areas with the contaminated atmosphere.

[2]. Values of deductions for maintenance/servicing according to data of Giprokommunenergo.

[3]. Values calculated for maintenance/servicing are given within limits, indicated in [21].

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The coefficients of the annual deductions to the renovation, the major overhaul and the maintenance/servicing for the lines of electrical networks in the dependence on their design for the

transformer substations, distributors and power electrical equipment are given in Table 10-2. In this table the values of the deductions to the renovation are calculated according to formula (10-5) and data of Table 10-1.

In general in the presence of structural members with the different values of total annual deductions expenditures are determined from to the formula

$$З=\Sigma pK+C_{э}, \text{ руб.} (1) \qquad (10\text{-}6)$$

Key: (1). rub.

During the determination of total expenditures for the object whose construction is realized on development stages, it is necessary to provide for bringing all expenditures up to one moment/torque of the development of object.

The reduced expenditures are determined from to the formula

$$З=\sum_{t=1}^{T} З_t a^t, \text{ руб.} (1) \qquad (10\text{-}7)$$

Key: (1). rub.

where a - the reduction coefficient, equal to 0.87;

T - number of years of the calculated development period of the object;

$З_t$ - expenditure of the t year the development of object, rub:

$$З_t = (\Sigma pK)_t + \Delta C_{эt},\ руб.^{(1)} \qquad (10\text{-}8)$$

Key: (1). rub.

In formula (10-8):

$(\Sigma pK)_t$ - the yearly deductions from the means, inserted in the object in the t year, rub;

$\Delta C_{э.t}$ - change of the cost/value of losses in the t year in comparison with (t-1)-th year, rub.

For the first year the operation of object by $\Delta C_{эt}$ should be understood the total cost/value of the losses of electrical energy in this year.

The cost/value of the losses of electrical energy is determined from to the formula

$$C_э = \delta(\alpha K_м \Delta P_м + \beta \Delta A),\ руб.^{(1)} \qquad (10\text{-}9)$$

Key: (1). rub.

where $\Delta P_м$ - greatest losses of active power, kW;

ΔA - annual losses of electrical energy, kW•h;

$K_м$ - coefficient of the coincidence of design load of the projected/designed object with the maximum of the power system; it is accepted in the dependence on the graphs/curves of the load of object, and power system (with the coincidence of maximums $K_м=1$);

α - the specific expenditures, caused by the need of expanding the power plants for the compensation for power losses, rubles/kW;

β - specific expenditures for the expansion of the fuel resources for mining supplementary energy and on the payment to the prime cost of its consumption/production/generation, rubles/kW•h;

δ - coefficient, which considers an increase of the cost/value of electric power in the dependence on the distance of this object from the power supply.

Values α and β for different power systems of the USSR for 1970-1975 are given in Tables 10-3.

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The values of coefficient δ for the tentative calculations can be accepted within the limits:

Nets by the voltage are 110 kV and are higher ... δ=1.05-1.1.

Nets 6-35 kV ... δ=1.1-1.2.

Nets to 1000 V ... δ=1.2-1.3.

Formula (10-9) for determining the cost/value of the losses of electric power can be also represented in one of the following versions:

$$C_э=\gamma_1\Delta P_м,\ руб.;\ (1) \quad (10\text{-}10)$$

$$C_э=\gamma_2\Delta A,\ руб.,\ (1) \quad (10\text{-}11)$$

Key: (1). rub.

where γ_1 - a cost/value of 1 kW of the greatest losses of the active power:

$$\gamma_1=\delta(\alpha K_м+\beta\tau),\ руб/квт;\ (1) \quad (10\text{-}12)$$

Key: (1). rubles/kW.

γ_2 - cost/value 1 kW•h of the losses of the electrical energy:

$$\gamma_э = \delta\left(\frac{\alpha K_м}{\tau} + \beta\right), \text{ руб/квт·ч; (1)} \qquad (10\text{-}13)$$

Key: (1). rubles/kW•h.

τ - annual number of hours of the maximum losses of active power.

Example 10-1. To make the technical-economic comparison of two versions of the development of distribution network 10 kV of the city district under the following conditions.

Total cost/value of the reconstruction of the net of 90 thousand rub.

Yearly deductions from capital investments p=0.1756.

Value of the calculated development period of 3 years.

The 1st version. The reconstruction of net is made simultaneously in the first year of calculated period. The yearly cost/value of the losses of electrical energy for this version comprises:

The 1st year - 8 thousand rub; the 2nd year - 8.5 thousand rub;

the 3rd year - 9 thousand rub.

The 2nd version. The reconstruction of net is realized during 3 years with yearly investments of 30 thousand rub. The cost/value of the losses of electrical energy in this case comprises: the 1st year - 11 thousand rub; the 2nd year - 10 thousand rub; the 3rd year - 9 thousand rubles

Tables 10-3. Values cf values α and β, entering the formula of the cost/value of the annual losses of electric power for different areas OES to 1970-1975 (according tc the data institute Energoset'proyekt).

(1) Район	(2) α, руб/квт	(3) β, руб/квт·ч
(4) ОЭС Центра, Юга, Северо-запада, Закавказья, Поволжья и Урала	24,17	$0.469\cdot10^{-2}$
(5) ОЭС Дальнего Востока и Забайкалья	28,6	$0,294\cdot20^{-2}$
(6) ОЭС Средней Азии	20,65	$0,223\cdot10^{-2}$
(7) ОЭС Центральной Сибири и Северного Казахстана	25,36	$0.075\cdot10^{-2}$

Key: (1). Area. (2). rubles/kW. (3). rubles/kW•h. (4). OES of center, south, northwest, Transcaucasia, Volga area and Urals. (5). OES of Far East and Transbaykal. (6). OES of Central Asia. (7). OES of central Siberia and North Kazakhstan.

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Solution. According tc formula (10-8) we determine expenditures for the first version:

$$З_1 = (0,1756\cdot 90+8)\cdot 0,87 + (8,5-8)\cdot 0,87^2 + (9-8,5)\cdot 0,87^3 = 21,5 \text{ тыс. руб.; (1)}$$

Key: (1). thousand of rub.

for the second version

$$З_2 = (0,1756\cdot 30+11)\cdot 0,87 + [0,1756\cdot 30 + (10-11)]\cdot 0,87^2 + [0,1756\cdot 30+(9-10)]\cdot 0,87^3 = 20,1 \text{ тыс. руб. (1)}$$

Key: (1). thousand of rub.

The second version, which foresees the insertion of means in the reconstruction of net by equal portions during 3 years, proves to be more economical.

Example 10-2. To determine the cost/value of the losses of electrical energy in distribution network 380 V of the industrial enterprise, which obtains feed from OES of Urals, for the following values of a number of hours of the maximum losses: τ_1=2500 and τ_2=5000, if the annual losses of electrical energy in the net comprise:

$$\Delta A = 800\,000\ \text{kW}\cdot\text{h} \text{ and } K_м = 1.$$

Solution. The cost/value of the losses of electrical energy we determine from formulas (10-13) and (10-11). Through Tables 10-3 we find for OES of Urals the values of coefficients of a and β:

$$\alpha = 24{,}17\ руб/квт;\ (1)$$
$$\beta = 0{,}469\cdot 10^{-2}\ руб/квт\cdot ч.\ (2)$$

Key: (1). rubles/kW. (2). rubles/kW•h.

After accepting the values of coefficient δ=1.3 let us find:

for a number of hours of the maximum losses τ_1=2500

$$\gamma_1 = 1{,}3\left(\frac{24{,}17\cdot 1}{2\,500} + 0{,}469\cdot 10^{-2}\right) = 0{,}0186\ руб/квт\cdot ч;\ (1)$$
$$C_{э1} = 0{,}0186\cdot 800\,000 = 14\,900\ руб.;\ (2)$$

Key: (1). rubles/kW•h. (2). rub.

for a number of hours cr tne losses τ_2=5000

$$\gamma_2 = 1,3\left(\frac{24,17\cdot 1}{5\,000} + 0,469\cdot 10^{-2}\right) = 0,0123 \text{ руб/квт}\cdot\text{ч (1)};$$

$$C_{э2} = 0,0123\cdot 800\,000 = 9\,830 \text{ руб. (2)}$$

Key: (1). rubles/kW•h. (2). rub.

Table 10-4. Cost/value of the construction 1 km of aerial line to 1 kV (without the cost/value of wires).

(1) Конструкция опор	(2) Районы СССР		(3) Стоимость, руб.
	(4) по гололеду	(5) по скоростному напору ветра	
(6) Деревянные опоры с деревянными приставками	I—II	I—IV	912
	III	II—IV	973
	IV	III—IV	1 230
(7) Деревянные опоры с железобетонными приставками	I—II	I—IV	946
	III	II—IV	1 024
	IV	III—IV	1 301
(8) Железобетонные опоры	I—II	I—II	843
	III	III—IV	897

Key: (1). Construction/design of supports. (2). Areas. (3). Cost/value, rub. (4). on ice-covered surface. (5). on velocity head of wind. (6). Wooden supports with wooden attachments. (7). Wooden supports with reinforced concrete attachments. (8). Reinforced concrete supports.

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Table 10-4-10-14 gives the enlarged indices of the cost/value of air and cable lines, transformer substations, distributors and capacitor banks [1].

FOOTNOTE [1]. The enlarged indices and values during calculations must

be corrected on the operating price lists. ENDFOOTNOTE.

Tables 10-4 and 10-5 are comprised according to the data of VNIPIsel'elektro, remaining tables - according to the data of the Rostov Department of the Institute of Elektroproyekt. The tables indicated are intended for the use during the technical-economic calculations.

Table 10-5. Cost/value of the mounting 1 km of the wire of line to 1 kV on the established/installed supports.

(1) Марка и сечение проводов	ПСО-4	ПСО-5	ПС-25	ПС-35	АС-16
(2) Стоимость, руб.	38,5	55,4	62,9	96,3	74,6

Продолжение

(1) Марка и сечение проводов	АС-25	А-16	А-25	А-35	А-50	А-70
(2) Стоимость, руб.	108,2	69,3	92,8	113,1	141,2	204,6

Key: (1). Brand and the section of wires. (2). Cost/value, rub.

Table 10-6. Cost/value of the construction 1 km of aerial line 6-10 kV.

(1) Марка и сечение проводов	(2) Стоимость, руб.		
	(3) Деревянные опоры	(4) Деревянные опоры с железобетонными приставками	(5) Железобетонные опоры
А-25	—	—	800
А-35	1 275	1 065	850
А-50	1 380	1 165	910
А-70	1 495	1 280	1 155
А-95	1 695	1 505	1 315
А-120	1 840	1 650	1 435
АС-16	1 070	910	—
АС-25	1 105	955	830
АС-35	1 260	1 090	960
АС-50	1 365	1 225	1 095
АС-70	1 560	1 405	1 255
ПС-25	965	885	830
ПС-35	1 010	930	850
ПС-50	1 125	1 005	900
ПСО-4	—	—	655
ПСО-5	—	—	675

Note: 1. Table gives the cost/value of the lines, planned in the unpopulated locality in the I area of climatic conditions on the ice-covered surface for the first group of structures of Moscow

region.

2. During composition of technical-economic calculations for areas are considered coefficients: for II climatic area in ice-covered surface K=1.1, for III area K=1.2, for IV area K=1.35.

3. During construction of line under urban conditions and in sections of industrial building-up is applied coefficient K=1.52.

Key: (1). Brand and the section of wires. (2). Cost/value, rub. (3). Wooden supports. (4). Wooden supports with reinforced concrete attachments. (5). Reinforced concrete supports.

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Table 10-7. Cost/value cf tne separator 1 km cf cables 1.6 and 10 kV.

(1) Условие прокладки	(2) Номинальное напряжение, кв	(3) Материал жил	(4) Марка кабеля	(5) Число жил	(6) Стоимость прокладки 1 км кабеля (руб.) при сечении, мм²													
					2.5	4	6	10	16	25	35	50	70	95	120	150	185	240
(7) В траншее	1	М	СБ	3	820	890	990	1 150	1 400	1 740	2 080	2 600	3 270	4 130	4 980	5 960	7 280	9 050
			АБ	3	—	—	880	1 040	1 250	1 490	1 620	2 270	2 860	3 620	4 370	—	—	—
			СБ	4	—	920	1 010	1 200	1 480	1 830	2 250	2 810	3 780	3 610	5 560	6 680	8 130	—
			АБ	4	—	—	930	1 090	1 350	1 660	2 040	2 600	3 250	4 130	—	—	—	—
		А	АСБ	3	810	830	910	1 020	1 200	1 350	1 560	1 820	2 190	2 618	3 140	3 610	4 250	5 280
			ААБ	3	—	—	800	880	1 000	1 100	1 260	1 470	1 710	2 010	2 300	2 650	3 230	4 140
			АПВБ	3	760	800	860	970	1 140	1 270	1 460	1 620	1 950	2 360	2 820	3 240	—	—
			АСБ	4	—	880	960	1 090	1 300	1 480	1 750	2 090	2 550	3 140	3 680	4 220	4 960	—
			ААБ	4	—	—	820	900	1 050	1 220	1 420	1 640	1 900	2 210	—	—	—	—
			АПВБ	4	810	840	900	1 010	1 190	1 380	1 560	1 839	2 140	2 630	2 950	3 400	—	—
	6	М	СБ	3	—	—	—	1 740	2 030	2 330	2 730	3 330	4 020	4 920	5 790	6 730	8 040	9 790
			АБ	3	—	—	—	1 470	1 670	1 920	2 290	2 760	3 300	—	—	—	—	—
		А	АСБ	3	—	—	—	1 640	1 820	2 000	2 300	2 620	3 000	3 490	3 980	4 460	5 070	5 910
			ААБ	3	—	—	—	1 330	1 450	1 560	1 720	1 970	2 180	2 500	2 760	3 060	3 550	4 070
			АПВБ	3	—	—	—	1 490	1 590	1 770	1 950	2 230	2 620	3 060	3 490	3 840	—	—
	10	М	СБ	3	—	—	—	—	2 500	2 760	3 180	3 740	4 420	5 300	6 160	7 320	8 530	10 330
		А	АСБ	3	—	—	—	—	2 340	2 470	2 770	3 080	3 420	3 900	4 390	4 910	5 575	6 600
			ААБ	3	—	—	—	—	1 640	1 750	1 980	2 190	2 480	2 960	3 300	3 580	4 420	—
			АПВБ	3	—	—	—	—	3 000	3 350	3 730	4 060	4 500	5 090	5 610	6 180	—	—
(8) В канале, туннеле или по эстакадам	1	М	СБГ	3	850	910	1 010	1 180	1 410	1 710	2 050	2 580	3 230	4 080	4 930	5 980	7 090	9 070
			АБГ	3	—	—	910	1 050	1 250	1 500	1 630	2 250	2 870	3 620	4 350	—	—	—
			СБГ	4	—	940	1 030	1 220	1 470	1 800	2 190	2 780	3 750	4 530	5 500	6 670	8 060	—
			АБГ	4	—	—	950	1 110	1 350	1 670	2 030	2 550	3 270	4 110	—	—	—	—
		А	АСБГ	3	820	850	920	1 030	1 200	1 340	1 530	1 780	2 140	2 620	3 070	3 530	4 150	5 160
			ААБГ	3	—	—	830	900	1 010	1 110	1 270	1 460	1 680	1 980	2 260	—	—	—
			АПВГ	3	540	570	610	690	760	860	970	1 130	1 330	1 570	1 830	2 130	—	—
			АСБГ	4	—	900	970	1 100	1 290	1 450	1 710	2 040	2 510	3 070	3 590	4 130	4 840	—
			ААБГ	4	—	—	850	940	1 050	1 230	1 400	1 610	1 880	2 170	—	—	—	—
			АПВГ	4	580	600	640	720	810	950	1 100	1 300	1 530	1 810	2 090	2 480	—	—
	6	М	СБГ	3	—	—	—	1 670	1 960	2 240	2 680	3 250	3 920	4 820	5 680	6 620	7 900	9 610
			АБГ	3	—	—	—	1 420	1 610	1 860	2 240	2 710	3 260	—	—	—	—	—
		А	АСБГ	3	—	—	—	1 570	1 730	1 910	2 200	2 550	2 900	3 370	3 840	4 390	4 920	5 690
			ААБГ	3	—	—	—	1 280	1 390	1 500	1 720	1 910	2 120	—	—	—	—	—
			АПВГ	3	—	—	—	1 030	1 220	1 340	1 590	1 700	1 990	2 260	2 570	2 950	—	—
	10	М	СБГ	3	—	—	—	—	2 430	2 700	3 090	3 630	4 290	5 190	6 040	7 170	8 360	10 160
		А	АСБГ	3	—	—	—	—	2 220	2 400	2 670	2 970	3 310	3 760	4 220	4 700	5 390	6 410
			АПВГ	3	—	—	—	—	2 650	2 970	3 330	3 630	4 050	4 510	5 110	5 670	—	—
(9) В блоке	1	М	СГТ	3	820	880	980	1 180	1 450	1 800	2 150	2 650	3 410	4 320	5 220	6 310	7 600	—
	6	М	СГТ	3	—	—	—	1 830	2 100	2 410	3 390	3 920	4 670	5 600	6 140	7 190	8 590	—
	10	М	СГТ	3	—	—	—	—	2 580	2 970	3 390	3 950	4 680	5 640	6 550	7 510	9 210	—

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(10) По лот-кам	1	М	СБГ	3	790	840	950	1 110	1 350	1 650	2 030	2 520	3 180	4 140	4 960	5 930	7 160	9 110
			АБГ	3	—	—	840	990	1 190	1 440	1 610	2 120	2 810	3 670	4 410	—	—	—
			СБГ	4	—	880	970	1 160	1 400	1 740	2 180	2 730	3 700	4 590	5 530	6 620	7 980	—
			АБГ	4	—	—	890	1 050	1 290	1 600	2 010	2 540	3 220	4 160	—	—	—	—
		А	АСБГ	3	760	790	860	970	1 140	1 270	1 520	1 760	2 120	2 680	3 130	3 580	4 250	5 350
			ААБГ	3	—	—	770	830	950	1 050	1 250	1 440	1 660	2 070	2 340	—	—	—
			АПВГ	3	510	530	580	660	720	820	950	1 100	1 310	1 550	1 807	2 120	—	—
			АСБГ	4	—	840	910	1 030	1 220	1 390	1 700	2 020	2 460	3 120	3 650	4 190	4 930	—
			ААБГ	4	—	—	790	870	990	1 160	1 390	1 590	1 860	2 260	—	—	—	—
			АПВГ	4	550	570	610	690	780	910	1 070	1 270	1 510	1 790	2 060	2 460	—	—
	6	М	СБГ	3	—	—	—	1 600	1 890	2 170	2 630	3 200	3 870	4 840	5 700	6 630	7 820	9 640
		М	АБГ	3	—	—	—	1 350	1 540	1 790	2 210	2 660	3 210	—	—	—	—	—
		А	АСБГ	3	—	—	—	1 510	1 670	1 850	2 170	2 490	2 850	3 430	3 890	4 350	5 010	5 930
			ААБГ	3	—	—	—	1 210	1 320	1 430	1 690	1 880	2 090	—	—	—	—	—
			АПВГ	3	—	—	—	1 000	1 190	1 310	1 560	1 670	1 960	2 230	2 540	2 920	—	—
	10	М	СБГ	3	—	—	—	—	2 340	2 610	3 040	3 580	4 230	5 210	6 060	7 040	8 280	10 150
		А	АСБГ	3	—	—	—	—	2 150	2 300	2 610	2 920	3 250	3 820	4 280	4 680	5 480	6 450

Note. The cost/value of trenches, constructions/designs and chutes/trays calculates additionally on the basis of tables 10-8, 10-9 and 10-10.

Key: (1). Condition of separator. (2). nominal voltage, kV. (3). Material of core. (4). Cable make-up. (5). Number of cores. (6). Cost/value of separator 1 km of cable (rub) with section, mm². (7). In trench. (8). In channel, tunnel or on piers. (9). In block. (10). On chutes/trays.

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Table 10-8. Cost/value of chutes/trays and composite constructions/designs for the cable laying in the channels and the tunnels.

(1) Наименование		(2) Единица измерения	(3) Стоимость, руб.
(4) Лотки штампованные	—	m	520
(5) Сборные конструкции при количестве полок	3	100 компл. (6)	150
	4		170
	5		190

Key: (1). Designation. (2). Unit measurement. (3). Cost/value, rub. (4). Chutes/trays, stamped/die-forged. (5). Composite constructions/designs with quantity of shelves. (6). sets.

Table 10-9. Cost/value of trenches on 1 running km.

TABLE 10-9.

(1) Траншея	(2) Количество кабелей	(3) Стоимость, руб, при категории грунта I	II	III
(4) С учетом стоимости переходов, разборки и восстановления *мостовой, стоимости блоков,* труб, кирпича и песка	1	1 770	2 010	2 230
	2	2 490	2 815	3 085
	3	3 240	3 640	3 970
	4	4 010	4 520	4 930
	5	4 805	5 415	5 900
	6	5 575	6 295	6 865
	7	6 505	7 330	7 970
	8	7 445	8 335	9 050
	9	8 375	9 375	10 160
	10	9 315	10 410	11 275
(5) Без учета стоимости переходов	1	610	695	825
	2	760	840	980
	3	930	1 010	1 030
	4	1 135	1 235	1 420
	5	1 360	1 470	1 690
	6	1 560	1 695	1 945
	7	1 915	2 080	2 360
	8	2 270	2 430	2 740
	9	2 645	2 815	3 155
	10	3 015	3 200	3 570

Note. Digging and charging of trenches are conducted by hand.

Key: (1). Trenches. (2). Quantity of cables. (3). Cost/value, rub, with category of soil. (4). Taking into account cost/value of transitions/junctions, dismantling and restoration/reduction of bridge, cost/value of blocks, tubes, brick and sand. (5). Without account to cost/value of transitions/junctions.

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Table 10-10. Cost/value cr tlccks, channels, tunnels, piers on 1 running km.

(1) Наименование и характеристика			(2) Стоимость, руб.	
			(3) Сухой грунт	(4) Мокрый грунт
(5) Блоки	(6) При числе отверстий (с учетом колодцев): 2		12 100	—
	4		14 200	—
	6		16 200	—
	8		18 200	—
	10		20 200	—
(9) Каналы, включая переходы под железнодорожными путями и автодорогами	(7) Каналы заглубленные (700 мм от уровня земли)	(8) Сечение, мм 900×600	27 670	35 670
		600×600	22 200	28 500
		600×450	19 400	25 000
	(10) Каналы заглубленные усиленные (500 мм от уровня земли)	300×600	32 970	40 970
		600×600	26 350	32 800
		600×450	23 100	28 600
	(11) Каналы полузаглубленные (200 мм от уровня земли)	900×600	26 880	34 880
		600×600	21 600	27 980
		600×450	18 850	24 450
(12) Туннели	(13) Проходные	2 000×2 200	74 000	87 500
	(14) Полупроходные	1 500×6 000	120 000	144 000
(14) Галереи и эстакады	(15) Тип 1 (одноцепный) силовых кабелей 18—42, контрольных 60—102		63 000	96 000
	(16) Тип 2 (галерейный) силовых кабелей 54—126, контрольных 180—306		95 000	150 000
	(17) При совмещенной прокладке кабелей по эстакадам с технологическими трубопроводами		20 000	—

Note. In cost is takan intc ccnsideraticn entire complex of construction work, incluċing tke ccst/value cf materials.

Key: (1). Name and characteristic. (2). Cost/value, rub. (3). Dry soil. (4). Wet soil. (5). Elccks. (6). With rumber cf openings (taking into account pits). (7). Channels, sunk (700 mm frcm ground

level). (8). Section, mm. (9). Channels, including transitions/junctions under railway lines and highways. (10). Channels sunk intensified (300 mm from ground level). (11). Channels, partly buried (200 mm from ground level). (12). Tunnels. (13). Passage. (14). Semiaccess. (15). Type of 1 (singe-circuit) power cables 18-42, control rooms 60-102. (16). Galleries and pier. (17). With combined cable laying on piers with technolcgical conduits/manifolds.

Table 10-11. Cost/value cf transfcrmer substaticns.

(1) Наименование	(2) Мощность трансфор-матора, ква	(3) Стоимость ТП, тыс. руб.	
		(4) с одним транс-форматором	(5) с двумя транс-форматорами
(6) Отдельно стоящая трансформаторная подстанция 6—10/0,4 *кв* по типовому проекту Гипрокоммунэнерго	100	2,81	6,79
	160	3,20	7,24
	250	3,23	7,60
	400	3,42	7,97
	630	4,69	10,49
(7) Комплектная трансформаторная подстанция типа КТП 6/0,4 *кв*	180	4,16	—
	320	4,37	9,06
	560	6,07	12,27
	400	4,09	8,53
	630	11,46	22,70
	1 000	12,97	26,04
(8) Мачтовые киоски 6/04 *кв*	100	1,23	—
	160	1,34	—
	250	1,64	—

Key: (1). Designation. (2). Fower cf transfcrmer, kVA. (3). Cost/value TP, thousand cf ruc. (4). with one transfcrmer. (5). with two transformers. (6). Separate transformer substation 6-10/0.4 kg on standard project Giprckcmmunenergc. (7). Ganged transfcrmer substation of type KTP cf 6/0.4 kV. (8). Mast tcwers 6/0.4 kV.

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Table 10-12. Cost/value cf distributors to 10 kV of the type KSO-2 UM.

(1) Наименование	(2) Тип привода или трансформатора напряжения	(3) Номинальный ток, а	(4) Стоимость, руб.
(5) Ввод и трансформатор напряжения	НТМИ (НТМК)	600	927
(6) Ввод или отходящая линия с МВ*) типа ВМП	ППМ (П) ПЭ (ПС)	1 000 1 000	2 153 1 933
(7) Ввод или отходящая линия с МВ типа ВМП	ППМ (П) ПЭ (ПС)	1 500 1 500	3 051 2 881
(8) Ввод от силового трансформатора с МВ типа ВМП	ППМ (П) ППМ (П) ПЭ (ПС) ПЭ (ПС)	1 500 3 000 1 500 3 000	3 031 3 451 2 801 3 111
(9) Ввод от силового трансформатора и трансформатора собственных нужд до 63 *ква*	ППМ (П) ППМ (П) ПЭ (ПС) ПЭ (ПС)	1 500 3 000 1 500 3 000	3 361 3 741 3 231 3 501
(10) Проходной ввод с МВ типа ВМП	ППМ (П) ПЭ (ПС)	1 500 1 500	3 031 2 801
(11) Ввод и трансформатор собственных нужд ТМ-25/10, ОМ-4/10	ППМ (П) ПЭ (ПС)	1 500 1 500	3 341 3 341
(12) Отходящая линия с МВ типа ВМП	ППМ (П) ПЭ (ПС)	1 500 1 500	2 113 1 813
(13) Отходящая линия	ПР-2	400	777
(14) Отходящая линия или ввод	ПРА-17	400	803
(15) То же	ПРА-17	400	903
(16) Секционный разъединитель	ПР-2	600	467
(17) Секционный выключатель типа ВМП с трансформатором напряжения НТМИ (НТМК)	ППМ (П) ППМ (П) ПЭ (ПС) ПЭ (ПС)	1 500 3 000 1 500 3 000	3 231 3 571 3 221 3 391
(18) Секционный выключатель типа ВМП	ППМ (П) ППМ (П) ПЭ (ПС) ПЭ (ПС)	1 500 3 000 1 500 3 000	2 871 3 151 2 861 3 031

(19) Трансформатор напряжения НТМИ (НТМК) НОМ	НТМИ	400	897
(20) Разрядники	РВМ (РВП)	400	707
(21) Трансформатор напряжения и разрядники РВМ (РВП)	НТМИ (НТМК)	400	987
(22) Трансформатор напряжения с конденсаторами	НТМИ (НТМК)	400	837
(23) Для реакторного пуска электродвигателя с выключателем типа ВМП	ППМ (П) ПЭ (ПС)	1 500 1 500	4 574 4 544
(24) Для реакторного пуска и динамического торможения электродвигателя с выключателем типа ВМП	ППМ (П) ПЭ (ПС)	1 000 1 000	5 927 5 907
(25) Для автотрансформаторного пуска и динамического торможения электродвигателя с выключателем типа ВМП	ППМ (П) ПЭ (ПС)	1 000 1 000	7 640 7 540
(26) Отходящая линия к трансформатору со схемой У/Д с выключателем типа ВМП	ППМ (П) ПЭ (ПС)	1 500 1 500	2 293 2 173
(27) Резервная камера, ввод, заземление сборных шин	ПР-2	1 500	597

Key: (1). Designation. (2). Type of drive or voltage transformer. (3). Rated current, A. (4). Cost/value, rub. (5). Introduction/input and voltage transformer. (6). Introduction/input or waste/exiting line with MV[1] of type VMP.

FOOTNOTE [1]. MV - oil breaker. ENDFOOTNOTE.

(7). Introduction/input or waste/exiting line with MV of type VMP.
(8). Introduction/input from power transformer with MV of type VMP.
(9). Introduction/input from power transformer and transformer of its

own needs to 63 kVA. (10). Passage introduction/input with MV of type VMP. (11). Introduction/input and transformer of its own needs TM-25/10, OM-4/10. (11). Introduction/input and transformer of its own needs TM-25/10, OM-4/10. (12). Waste/exiting line with MV of type VMP. (13). Waste/exiting line with MV of type VMP. (14). Waste/exiting line or introduction/input. (15). Then. (16). Sectional disconnector. (17). Sectionalizing switch of type VMP with voltage transformer NTMI (NTMK). (18). Sectionalizing switch of type VMP. (19). Voltage transformer NTMI (NTMK) NOM. (20). Dischargers/gaps. (21). Voltage transformer and dischargers/gaps RVM (RVP). (22). Voltage transformer with capacitors/condensers. (23). For reactor launching/starting of electric motor with switch of type VMP. (24). For reactor launching/starting and dynamic braking of electric motor with switch of type VMP. (25). For autoinductive launching/starting and dynamic braking of electric motor with switch of type VMP. (26). Waste/exiting line to transformer with diagram U/D with switch of type VMP. (27). Stand-by chamber/camera, introduction/input, grounding of collecting mains.

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Table 10-13. Cost/value cf distributors to 10 kV of types KRU and KRUN.

(1) Наименование	(2) Стоимость, руб.
(3) *Комплектные распределительные устройства КРУ2-10 ПЭ*	
(4) Ячейка с выключателем типа ВМП с приводом типа ППМ-10	3 060
(5) То же с приводом типа ПЭ-11	2 850
(6) Ячейка с трансформатором напряжения	1 650
(7) Ячейка с разъединителем или кабельная сборка	1 140
(8) Ячейка с разрядниками	1 150
(9) Ячейка с трансформатором собственных нужд ТМ-2	1 630
(10) Шинопроводы	620
(3) *Комплектные распределительные устройства КРУ-К-III У*	
(4) Ячейка с выключателем типа ВМП с приводом типа ППМ-10	2 120
(5) То же с приводом типа ПЭ-11	1 970
(6) Ячейка с трансформатором напряжения	890
(11) Ячейка с трансформатором напряжения и разрядниками	990
(8) Ячейка с разрядниками	740
(9) Ячейка с трансформатором собственных нужд	840
(12) Ячейка с предохранителями	690
(3) *Комплектные распределительные устройства КРУН-К-IV У*	
(13) Ячейка с масляным выключателем типа ВМГ и приводом типа ППМ	1 655
(5) То же с приводом типа ПП/УМП	1 495
(13) Ячейка с масляным выключателем типа ВМП и приводом типа ППМ	2 405
(5) То же с приводом типа ПП (УПГП)	2 245
(11) Ячейка с трансформатором напряжения и разрядниками	985
(6) Ячейка с трансформатором напряжения	905
(8) Ячейка с разрядниками	765
(14) Ячейка секционирования с разъединительными контактами	905
(15) Ячейка с трансформатором собственных нужд до 63 *ква*	1 215
(3) *Комплектные распределительные устройства КРУН-К-УП*	
(13) Ячейка с масляным выключателем типа МГГ и приводом типа ПЭ-2	2 115
(16) Ячейка секционирования с выключателем МГГ	1 815
(14) Ячейка секционирования с разъединяющими контактами	1 105
(17) Шкаф ввода с разъединителем	905
(18) Ячейка с трансформатором собственных нужд 100 *ква*	1 295
(19) Ячейка с трансформатором собственных нужд 160 *ква*	1 505

Key: (1). Designation. (2). Cost/value, rub. (3). Cubic switchboards.

(4). Cell with switch of type VMP with drive of type. (5). Then with drive of type. (6). Cell with voltage transformer. (7). Cell with disconnector or cable assembly. (8). Cell with dischargers/gaps. (9). Cell with transformer of its own needs. (10). Busbars. (11). Cell with voltage transformer and dischargers/gaps. (12). Cell with safety devices/fuses. (13). Cell with oil breaker of type VMG and drive of type PPM. (14). Cell of partitioning with disconnecting contacts. (15). Cell with transformer of its own needs to 63 kVA. (16). Cell of partitioning by switch MGG. (17). Cabinet of introduction/input with disconnector. (18). Cell with transformer of its own needs of 100 kVA.

table 10-14. Condenser/capacitor installations 0.38; 6 and 10 kV of the Ust'-Kamenogorsk condenser/capacitor plant.

(1) Наименование	(2) Стоимость, руб.	(3) Удельная стоимость, руб/квар
(4) *Конденсаторные батареи напряжением 0,38 кв внутренней установки*		
ККУ-0,38-I, 80 (5) *квар*	1 080	13,5
ККУ-0,38-III, 160 (5) *квар*	1 925	12
ККУ-0,38-III, 160 *квар*, (6) с БРВ-1	2 085	13
ККУ-0,38-V, 280 (5) *квар*	2 965	10,6
ККУ-0-38-V, 280 *квар*, (6) с БРВ-1	3 135	11,2
(4) *Конденсаторные батареи напряжением 6—10 кв внутренней установки*		
КУ-6-I, 330 (5) *квар*	2 165	6,6
КУ-6-I, 330 *квар*, (6) с БРВ-2	2 320	7,0
КУ-6-II, 500 *квар*	3 070	6,15
КУ-6-II, 500 *квар*, (6) с БРВ-2	3 230	6,45
КУ-10-I, 330 *квар*	2 180	6,6
КУ-10-I, 330 *квар*, (6) с БРВ-2	2 335	7,1
КУ-10-II, 500 *квар*	3 075	6,15
КУ-10-II, 500 *квар*, (6) с БРВ-2	3 235	6,45
(7) *Конденсаторные батареи напряжением 6—10 кв наружной установки*		
КУН-6-II, 420 (5) *квар*	2 220	5,3
КУН-6-II, 420 *квар*, (6) с БРВ-2	2 375	5,65
КУН-10-II, 400 *квар*	2 320	5,8
КУН-10-II, 400 *квар*, (6) с БРВ-2	2 480	6,2

Key: (1). Designation. (2). Cost/value, rub. (3). Specific cost/value, rubles/quarter. (4). Capacitor banks by voltage 0.38 kV of internal installation. (5). kilovar. (6). s. (7). Capacitor banks by voltage 6-10 kV of external installation.

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Section Eleven

REGULATING VOLTAGE AND COMPENSATION FOR REACTIVE POWER.

11-1. Basic condition/positions.

The problem of regulating the voltage in the electric nets is the guarantee of normal technical specifications and efficiency/cost-effectiveness of the joint operation of the electric nets, electrical receivers and connected with them production mechanisms.

Questions of balance and distribution of reactive power, selection and arrangement/position of its sources, increase in the factor of power and efficiency/cost-effectiveness of the work of electrical networks must be examined together with questions of regulating voltage.

The fundamental method of regulating the voltage in distribution networks 6-20 kV is regulating in the centers of feed (TsP). By TsP are implied the busbars 6-20 kV of the distributors of reducing

substations or electrical stations.

All transformers in TsP must be established/installed with the device/equipment of regulating load stress (RPN). Failure of the use/application on the reducing substations with the secondary voltage 6-20 kV of transformers with RPN must be based by the technical-economic calculation.

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Table 11-1. Fundamental parameters of power tank transformers and autotransformers with RPN.

(1) Тип трансформатора или автотрансформатора	(2) Номинальная мощность, Мва	(3) Класс напряжения, кв	(4) Номинальные напряжения обмоток, кв			(5) Схема и группа соединений обмоток
			ВН	СН	НН	
(6) *Трансформаторы трехфазные двухобмоточные, РПН ±10%, ±6 ступеней*						
ТМН	0,063	10	6; 10		0,23; 0,4	$У/У_н$—0
ТМН	0,063	10	6; 10		0,4	$У/Z_н$—11
ТМН	0,1	10	6; 10		0,23; 0,4	$У/У_н$—0
ТМН	0,1	10	6; 10		0,4	$У/Z_н$—11
ТМН	0,16	10	6; 10		0,23; 0,4	$У/У_н$—0
ТМН	0,16	10	6; 10		0,4	$У/Z_н$—11
ТМН	0,16	10	6; 10		0,69	У/Д—11
ТМН	0,25	10	6; 10		0,23; 0,4	$У/У_н$—0
ТМН	0,25	10	6; 10		0,4	$У/Z_н$—11
ТМН	0,25	10	6; 10		0,69	У/Д—11
ТМН	0,4	10	6; 10		0,23; 0,4	$У/У_н$—0
ТМН	0,4	10	6; 10		0,4; 0,69	$Д/У_н$—11
ТМН	0,63	10	6; 10		0,4	$У/У_н$—0
ТМН	0,63	10	6; 10		0,4; 0,69	$Д/У_н$—11
ТМН	0,1	35	20; 35		0,23; 0,4	$У/У_н$—0
ТМН	0,1	35	20; 35		0,4	$У/Z_н$—11
ТМН	0,16	35	20; 35		0,23; 0,4	$У/У_н$—0
ТМН	0,16	35	20; 35		0,4	$У/Z_н$—11
ТМН	0,16	35	20; 35		0,69	У/Д—11
ТМН	0,25	35	20; 35		0,23; 0,4	$У/У_н$—0
ТМН	0,25	35	20; 35		0,4	$У/Z_н$—11
ТМН	0,25	35	20; 35		0,69	У/Д—11
ТМН	0,4	35	20; 35		0,23; 0,4	$У/У_н$—0
ТМН	0,4	35	20; 35		0,69	У/Д—11
ТМН	0,63	35	20; 27,5; 35		0,4	$У/У_н$—0
ТМН	0,63	35	20; 27,5; 35		0,69; 11	У/Д—11
ТМН	0,63	35	27,5; 35		6,3	У/Д—11
ТМН	1	10	6; 10		0,4	$У/У_н$—0
ТМН	1	10	6; 10		0,4; 0,69	Д/У—11
ТМН	1,6	10	6; 10		0,4	$У/У_н$—0
ТМН	1,6	10	10		0,4; 0,69	$Д/У_н$—11
ТМН	1,6	10	10		6,3	У/Д—11
ТМН	2,5	10	6; 10		0,69	$Д/У_н$—11
ТМН	2,5	10	10		6,3	У/Д—11
ТМН	4	10	10		6,3	У/Д—11
ТМН	6,3	10	10		6,3	У/Д—11
ТМНС	6,3	10	10		3,15	У/Д—11
ТМН	1	35	20; 35		0,4	$У/У_н$—0
ТМН	1	35	20; 35		6,3; 11	У/Д—11
ТМН	1	35	20		0,4; 0,69	$Д/У_н$—11
ТМН	1	35	35		0,69	$У/У_н$—0
ТМН	1,6	35	20; 35		0,4	$У/У_н$—0
ТМН	1,6	35	20; 35		6,3; 11	У/Д—11
ТМН	1,6	35	20		0,4; 0,69	$Д/У_н$—11
ТМН	1,6	35	35		0,69	$У/У_н$—0

ТМН	1,6	35	27,5		6,3; 11	У/Д—11
ТМН	2,5	35	20; 35		6,3; 11	У/Д—11
ТМН	2,5	35	20		0,69	Д/У—11
ТМН	2,5	35	35		0,69	У/Ун—11
ТМН	4	35	20; 35		6,3; 11	У/Д—11
ТМН	6,3	35	20; 35		6,3; 11	У/Д—11
(6) *Трансформаторы трехфазные двухобмоточные. РПН ±12% ±8 ступеней*						
ТДН	10	35	36,75		6,3; 10,5	Ун/Д—11
ТДН	16	35	36,75		6,3; 10,5	Ун/Д—11
ТДН	25	35	36,75		6,3; 10,5	Ун/Д—11
(7) *Трансформаторы трехфазные трехобмоточные. РПН ±12%. ±6 ступеней*						
ТМТН	6,3	35	35	10,5; 13,8	6,3	Ун/Д/Д—11—11
(8) *То же РПН±12%. ±8 ступеней*						
ТДТН	10	35	36,75	10,5; 13,8	6,3	Ун/Д/Д—11—11
ТДТН	16	35	36,75	10,5; 13,8	6,3	Ун/Д/Д—11—11
(9) *Трансформаторы трехфазные двухобмоточные. РПН ±12%. ±8 ступеней с напряжением к. з. 14%*						
ТДНС	10	35	10,5		3,15; 6,3	Ун/Д—11
ТДНС	10	35	13,8; 15,75		3,15	У/У—0
ТДНС	10	35	36,75		3,15	Ун/Д—11
(10) *То же с напряжением к. з., 10%*						
ТДНС	16	35	10,5; 13,8; 15,75; 18		6,3	Д/Д—0
ТДНС	16	35	36,75		6,3	Ун/Д—11
(11) *Трансформаторы трехфазные двухобмоточные с расщепленными обмотками. РПН ±12%. ±8 ступеней*						
ТРДН	25	35	15,75; 18,20		6,3/6,3 6,3/10,5	Д/Д—Д—0—0
ТРДН	25	35	36,75		6,3/6,3 6,3/10,5 10,5/10,5	Ун/Д—Д—11—11 или Д/Д—Д—0—0
ТРДН	32	35	15,75 20		6,3/6,3 6,3/10,5	Д/Д—Д—0—0
ТРДН	32	35	36,75		6,3/6,3 6,3/10,5 10,5/10,5	Ун/Д—Д—11—11 (12) или Д/Д—Д—0—0
ТРДН	40	35	20; 36,75		6,3/6,3 6,3/10,5	Д/Д—Д—0—0
ТРДН	40	35	36,75		10,5/10,5	Д/Д—Д—0—0
ТРДН	63	25	20 36,75		6,3/6,3 6,3/10,5	Д/Д—Д—0—0 Д/Д—Д—0—0
ТРДН	63	35	36,75		10,5/10,5	Д/Д—Д—0—0
(13) *Трансформаторы трехфазные двухобмоточные. РПН±16% в нейтрали ВН. ±9 ступеней*						
ТМН	2,5	110	110		6,6; 11; 22	Ун/Д—11
ТМН	6,3	110	115		6,6; 11; 22; 38,5	Ун/Д—11

ТДН	10	110	115		6,6; 11; 22; 38,5	$У_н$/Д—11
ТДН	16	110	115		6,6; 11; 22; 27,5; 38,5	$У_н$/Д—11
ТРДН	25	110	115		6,3/6,3 6,3/10,5 10,5/10,5	$У_н$/Д—Д—11—11
ТРДН	25	110	115		22; 27,5; 38,5	$У_н$/Д—11
ТРДН	32	110	115		6,3/6,3 6,3/10,5; 10,5/10,5	$У_н$/Д—Д—11—11
ТРДН	32	110	115		22; 38,5	$У_н$/Д—11
ТРДН	40	110	115		6,3/6,3 6,3/10,5; 10,5/10,5	$У_н$/Д—Д—11—11
ТРДН	40	110	115		22; 38,5	$У_н$/Д—11
ТРДЦН	63	110	115		6,3/6,3; 6,3/10,5; 10,5/10,5	$У_н$/Д—Д—11—11
ТРДЦН	63	110	115		22; 38,5	$У_н$/Д—11
ТРДЦН	80	110	115		6,3/6,3 6,3/10,5; 10,5/10,5	$У_н$/Д—Д—11—11
ТРДЦН	80	110	115		22; 38,5	$У_н$/Д—11

(13) *То же, с напряжением к. з., 16%*

ТРДНС	32	110	115		6,3/6,3; 6,3/10,5; 10,5/10,5	$У_н$/Д—Д—11—11
ТРДНС	40	110	115		6,3/6,3; 6,3/10,5; 10,5/10,5	$У_н$/Д—Д—11—11

(14) *Трансформаторы трехфазные трехобмоточные, РПН ±16% в нейтрали ВН, ±9 ступеней, с ПБВ на СН ±2 ×2,5%*

ТМТН	6,3	110	115	22; 38,5	6,6; 11	$У_н$/$У_н$/Д—0—11
ТДТН	10	110	115	22; 38,5	6,6; 11	$У_н$/$У_н$/Д—0—11
ТДТН	16	110	115	22; 27,5 38,5	6,6; 11	$У_н$/$У_н$/Д—0—11
ТДТН	25	110	115	11	6,6	У/Д/Д—11—11
ТДТН	25	110	115	22; 27,5 38,5	6,6; 11	$У_н$/$У_н$/Д—0—11
ТДТН	40	110	115	11	6,6	У/Д/Д—11—11
ТДТН	40	110	115	22; 27,5; 38,5	6,6; 11	$У_н$/$У_н$/Д—0—11
ТДТН	63	110	115	38,5	6,6; 11	$У_н$/$У_н$/Д—0—11
ТДЦТН	80	110	115	38,5	6,6; 11	$У_н$/$У_н$/Д—0—11

(15) *Трансформаторы трехфазные двухобмоточные, РПН ±12%, ±8 ступеней в нейтрали ВН*

ТМН	4	150	По ТУ		(16) По ТУ	Ун/Д—11
ТДН	16	150	158		3,3; 6,6; 11	Ун/Д—11
ТРДН	32	150	158		6,3/6,3; 6,3/10,5; 10,5/10,5	Ун/Д—Д—11—11
ТРДН	63	150	158		6,3/6,3; 6,3/10,5; 10,5/10,5	Ун/Д—Д—11—11

(17) *Трансформаторы трехфазные трехобмоточные, РПН ±12%, ±8 ступеней в нейтрали ВН*

ТДТН	16	150	158	22; 38,5	6,6; 11	Ун/Ун/Д—0—11
ТДТН	25	150	158	22; 27,5; 38,5	6,6; 11	Ун/Ун/Д—0—11
ТДТН	40	150	158	22; 38,5	6,6; 11	Ун/Ун/Д—0—11
ТДТН	63	150	158	22; 38,5	6,6; 11	Ун/Ун/Д—0—11

(18) *Автотрансформаторы трехфазные, РПН на стороне СН (в линии) ±12%, ±6 ступеней*

АТДТН	100	150	158	121	6,3; 10,5	Ун.авто/Д—0—11

(19) *Трансформаторы трехфазные двухобмоточные с расщепленной обмоткой, РПН ±12%, ±8 ступеней в нейтрали ВН*

ТРДН	32	220	230		6,3/6,3; 6,3/10,5; 10,5/10,5	Ун/Д—Д—11—11
ТРДЦН	32	220	230		22; 38,5	Ун/Д—11
ТРДЦН	63	220	230		6,3/6,3; 6,3/10,5; 10,5/10,5	Ун/Д—Д—11—11
ТРДЦН	63	220	230		22; 38,5	Ун/Д—11
ТРДЦН	100	220	230		10,5/10,5	Ун/Д—Д—11—11
ТРДЦН	100	220	230		22; 38,5	Ун/Д—11
ТРДЦН	160	220	230		10,5/10,5	Ун/Д—Д—11—11
ТРДЦН	160	220	230		22; 38,5	Ун/Д—11

(20) *Автотрансформаторы трехфазные трехобмоточные, РПН на стороне СН (в линии) ±12%, ±6 ступеней*

АТДТН	32	220	230	121	6,6; 11; 38,5	Ун.авто/Д—0—11
АТДТН	63	220	230	121	6,3; 10,5; 22; 27,5; 38,5	Ун.авто/Д—0—11
АТДЦТН	125	220	230	121	6,3; 10,5; 22; 38,5	Ун.авто/Д—0—11
АТДЦТН	160	220	230	121	6,3; 10,5; 22; 38,5	Ун.авто/Д—0—11
АТДЦТН	200	220	230	121	10,5; 13,8; 22; 38,5	Ун.авто/Д—0—11
АТДЦТН	250	220	230	121	10,5; 22; 38,5	Ун.авто/Д—0—11

(21) *Трансформаторы трехфазные двухобмоточные с расщепленной обмоткой, РПН ±12%, в нейтрали ВН*

ТРДЦН	32	330	330		6,3/6,3; 6,3/10,5; 10,5/10,5	Ун/Д—Д—11—11
ТРДЦН	32	330	330		22; 38,5	Ун/Д—11

ТРДЦН	63	330	330		6,3/6,3 6,3/10,5; 10,5/10,5	$У_н$/Д–Д–11–11
ТРДЦН	63	330	330		22; 38,5	$У_н$/Д–11
ТРДЦН	125	330	330		10,5/10,5	$У_н$/Д–Д–11–11
ТРДЦН	125	330	330		22	$У_н$/Д–11
ТРДЦН	200	330	330		10,5/10,5	$У_н$/Д–Д–11–11
ТРДЦН	200	330	330		22	$У_н$/Д–11

(22) *Автотрансформаторы трехфазные, РПН на стороне СН (в линии) ±12%*

АТДЦТН	63	330	330	115	10,5; 22; 38,5	$У_{н.авто}$/Д–0–11
АТДЦТН	125	330	330	115	6,3; 10,5; 22; 38,5	$У_{н.авто}$/Д–0–11
АТДЦТН	200	330	330	115	10,5; 22; 38,5	$У_{н.авто}$/Д–0–11
АТДЦТН	250	330	330	158	10,5; 22; 38,5	$У_{н.авто}$/Д–0–11
АТДЦТН	400	330	330	158	10,5; 22; 38,5	$У_{н.авто}$/Д–0–11
АТДЦТН	250	330	330	230	10,5; 22; 38,5	$У_{н.авто}$/Д–0–11
АТДЦТН	400	330	330	230	10,5; 22; 38,5	$У_{н.авто}$/Д–0–11

(23) *Автотрансформаторы трехфазные, РПН в нейтрали ±12%*

АТДЦТН	125	500	500	121	6,3; 10,5; 22; 38,5	$У_{н.авто}$/Д–0–11
АТДЦТН	250	500	500	115	10,5; 22; 38,5	$У_{н.авто}$/Д–0–11

(24) *Автотрансформаторы линейные регулировочные трехфазные, РПН ±10%, ±6 ступеней*

ЛТМ	0,4	10	6; 10		6; 10	$У_{н.авто}$
ЛТМ	0,63	10	6; 10		6; 10	$У_{н.авто}$
ЛТМ	0,63	35	20; 35		20; 35	$У_{н.авто}$

(25) *Автотрансформаторы линейные регулировочные трехфазные, РПН ±10%, ±8 ступеней*

ЛТМ	1,6	10	6; 10		6; 10	$У_{н.авто}$
ЛТМ	4	10	6; 10		6; 10	$У_{н.авто}$
ЛТМ	6,3	10	6; 10		6; 10	$У_{н.авто}$
ЛТМ-Р*	1,6	10	6; 10		6; 10	$У_{н.авто}$
ЛТМ-Р	4	10	6; 10		6; 10	$У_{н.авто}$
ЛТМ-Р	6,3	10	6; 10		6; 10	$У_{н.авто}$

(24) Автотрансформаторы линейные регулировочные трехфазные. РПН ±15%, число ступеней — по ТУ						
ЛТМ	16	10	6,3; 10,5		6,3; 10,5	$У_{н.авто}$
ЛТМ	25	10	6,3; 10,5		6,3; 10,5	$У_{н.авто}$
ЛТМ	25	35	36,75		36,75	$У_{н.авто}$
ЛТМ	40	10	6,3; 10,5		6,3; 10,5	$У_{н.авто}$
ЛТМ	63	35	10,5; 36,75		10,5; 36,75	$У_{н.авто}$
ЛТД	100	35	36,75		36,75	$У_{н.авто}$
(21) Автотрансформаторы линейные регулировочные трехфазные. РПН ±15%, число ступеней—по ТУ						
ЛТД	63	110	(19) По ТУ		(19) По ТУ	$У_{н.авто}$
ЛТД	125	110	(19) По ТУ		(19) По ТУ	$У_{н.авто}$

Key: (1). Type of transformer 11 of autotransformer. (2). Nominal power, MVA. (3). Class of voltage, kV. (4). Nominal voltages of windings, kV. (5). Diagram and group of connections of windings. (6). Transformers three-phase double wound, RPN +-10o/o, +-6c/c steps/stages. (7). Transformers three-phase triple-wound, RPN +-12o/o, +-6 steps/stages. (8). The same RPN +-12o/c, +-8 steps/stages. (9). Transformers of three-phase ones double wound, RPN +-12o/o, +-8 steps/stages with voltage short circuit, 14o/o. (10). Then with voltage short circuit, 10o/o. (11). Transformers three-phase double wound with split windings, RPN +-12o/o, +-8o/o steps/stages. (12). or. (13). Transformers three-phase double wound, RPN +-16c/o in neutral VN, +-9 steps/stages. (14). Transformers

three-phase triple-wound, RPN +-16o/o in neutral VN, +-9 steps/stages, with PBV to SN +-2x2.5o/o. (15). Transformers three-phase double wound, RPN +-12o/o, +-8o/o steps/stages in neutral VN. (16). On. (17). Transformers three-phase triple-wound, RPN +-12o/o, +-8 steps/stages in neutral VN. (18). Autotransformers three-phase, RPN on side SN (in line) +-12o/c, +-6 steps/stages. (19). Transformers three-phase double-wound with split winding, RPN +-12o/o, +-8 steps/stages in neutral VN. (20). Autotransformers three-phase triple-wound, RPN on side SN (in line) +-12o/o, +-6 steps/stages. (21). Transformers three-phase double wound with split winding, RPN +-12o/o, in neutral VN. (22). Autotransformers three-phase, RPN on side SN (in line) +-12o/c. (23). Autotransformers three-phase, RPN in neutral +-12o/c. (24). Autotransformers linear regulating three-phase, RPN +-10o/c, +-6 steps/stages. (25). Autotransformers linear regulating three-phase, RPN +-10o/o, +-8 steps/stages. (26). Autotransformers linear regulating three-phase, RPN +-15o/o, number of steps/stages - on TU. (27). Autotransformers linear regulating three-phase, RPN +-15o/o, number of steps/stages - on TU.

FOOTNOTE [1]. Autotransformers linear regulating with the letter "R" have the increased reactance, which ensures their dynamic stability

with the feed from the net of the unlimited power. ENDFOOTNOTE.

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On the existing substations with the fixed transformers must be provided for the installation of linear regulating autotransformers.

Regulating voltage in TsP must be automated.

Under normal conditions in TsP should be realized counter regulating, with which is provided the compensation for the loss of line voltage.

For distributive electrical networks with the electrical receivers which are characterized by the virtually uniform graphs/curves of changes of the loads with time, it is possible to be restricted to regulating voltage in TsP. If such regulating does not provide the necessary quality of voltage for the separate groups of users, should be applied the means of the local regulating of voltage.

For the realization of local regulating the voltages can be used:

1) automatically controlled capacitor banks;

2) synchronous motors with automatic regulating of field current;

3) the linear regulating autotransformers;

4) distribution transformers with RPN;

5) the individual adjusters in the transformers of technological aggregates/units (electric furnace, rectifying device/equipment, etc.).

Fundamental technical data of transformers and autotransformers with RPN according to a design of the "standardization of the transformers of the power ones of general purpose on 1967-1972" are given in Table 11-1.

11-2. Regulating voltage in TsP.

On the busbars TsP must be realized the contrary regulating of voltage at which the voltage is supported the higher, the greater the load of transformer.

Fig. 11-1 shows the range of changes in the voltage on the busbars TsP with changes in the load of transformer from the maximum to the minimum.

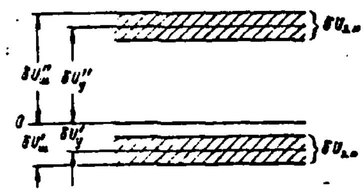

Fig. 11-1. Diagram of voltages on the busbars TsP with the contrary regulating.

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Here: $\delta U''_{м}$ — voltage error on the busbars TsP with the full load of transformer (upper boundary of dead zone), o/o; $\delta U'_{м}$ — voltage error on the busbars TsP with the smallest load of transformer (lower boundary of the zone of insensitivity), o/o; $\delta U''_{у}$ — voltage error, which corresponds to the average value of voltage with the full load of transformer, o/o; $\delta U'_{у}$ — the same with the smallest load of transformer, o/o; $\delta U_{з.н}$ — dead zone of the regulating device/equipment, o/o (values, are related to the mode/conditions of peak loads, they are noted by two primes, to the mode/conditions of minimum load - by one prime).

Dead zone is called the range of changes in voltage, with which does not occur functioning of control equipment.

The size of dead zone is accepted to 0.5-07o/o more than the step/stage of regulating.

Fig. 11-2 depicts diagram Isp the lengths of distribution network 6-20 kV, to which are connected the transformers with the transformation ratio 6-20/0.23-0.69 kV. It is assumed that the electrical receivers are connected only to the nets by voltage of up to 1000V.

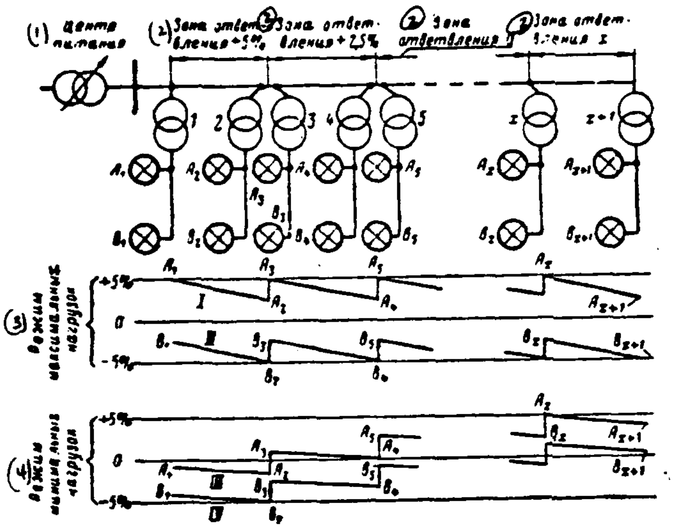

Fig. 11-2. Diagram of voltage errors on the terminals/grippers of the closest and outermost electrical receivers with the contrary of regulating on the busbars TsP.

Key: (1). Center of feed. (2). Zone of branching. (3). Mode/conditions of peak loads. (4). Mode/conditions of minimum loads.

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The parameters of net and the range of regulating on the busbars TsP must be selected in such a way that for all electrical receivers would be provided satisfaction of the condition

$$\delta U_{(+)} \geq \delta U \geq \delta U_{(-)}, \qquad (11\text{-}1)$$

where δU - a voltage error on the terminals/grippers of electrical

receiver, o/o; $\delta U_{(+)}$ and $\delta U_{(-)}$ — greatest respectively positive and negative voltage errors on the terminals/grippers of electrical receivers, permitted according to GOST 13109-67, o/o.

In the severe conditions can prove to be into depending on the mode/conditions of the work of net either nearest to the transformer electrical receivers $A_1, A_2, \ldots, A_{x+1}$, or outermost $B_1, B_2', \ldots, B_{x+1}'$.

If condition (11-1) will be satisfied for these receivers for all modes/conditions of the work of net, then it will be also satisfied for the remaining connected to the net receivers.

Fig. 11-2 depicts the diagrams of voltage errors on the terminals/grippers of the closest and outermost receivers for the modes/conditions of maximum and minimum loads. These diagrams are constructed on the assumption that the connected to the net load is uniform and graphs of changes of the active and reactive load with time are identical for all groups of electrical receivers. Under this condition the relation of the losses of voltage during the modes/conditions of minimum and peak loads will be in all elements/cells of net identical and equal to relation minimum I' and maximum I" the currents or transformer in TsP:

$$K = \frac{I'}{I''} \qquad (11\text{-}2)$$

Distribution transformers have five branchings: fundamental and

four supplementary +-2x2.5c/c whose switching is possible only with the off from the net transformer ("switching without the excitation" - PBV). To each branching corresponds the specific value of the addition of the voltage of transformer, which is determined from the formula

$$\delta U_{т} = \frac{\overset{*}{U}_{2н} - \overset{*}{U}_{1н}}{\overset{*}{U}_{1н}} \cdot 100, \%, \qquad (11\text{-}3)$$

where $\overset{*}{U}_{2н}$— relative value of nominal voltage, secondary winding of the transformer; $\overset{*}{U}_{1н}$— relative value of the nominal voltage of primary winding taking into account the used branching.

The values of the additions of voltage for distribution transformers are given in Table 11-2.

The line of distribution network 6-20 kV can be broken along the length to the zones, each of which corresponds to the specific branching of the winding of transformer. The nearest to TsP zone corresponds to branching +5c/c, for which addition the voltages smallest; after it are arranged/located the zone of the following branchings. Changes in the line voltage of up to 1000V on the boundary of two adjacent zones (cuts A_2A_3, A_4A_5 and so forth on the diagrams of voltages on Fig. 11-2) are equal to a difference in the additions of the voltages of the branchings of these zones.

For uniform loads can be determined the range of the contrary

regulating of voltage on the busbars TsP from $\delta U'_{T}$ to $\delta U''_{T}$, the permissible losses of line voltage to 1000V ΔU_{n} and into the net 6-20 kV ΔU_{nn} and also a number of utilized branchings of distribution transformers.

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During the derivation of the subsequent formulas it is accepted that the losses of voltage in all distribution transformers and from each transformer to the nearest electrical receiver are equal.

Fig. 11-3 shows the expressions, which are determining the losses of voltage in the elements/cells of net from busbars TsP to the terminals/grippers of electrical receivers, under the most unfavorable working conditions. The magnitudes of losses of voltage in the transformers are reduced by the values of the additions of voltage, which correspond to the branchings of windings accepted. In the numerators of fractions are shown the expressions, which relate to the mode/conditions of peak loads, in the denominator - to the mode/conditions of minimum loads.

Table 11-2. Values of the additicns of the vcltage cf transformers.

(1) Ответвление первичной обмотки трансформатора, %	(2) Величина добавки напряжения трансформатора, %			
	(3) Номинальное напряжение вторичной обмотки трансформатора, в			(4) Округленное значение добавки, %
	230	400	630	
+5	−0,43	0,25	−0,43	0
+2,5	2,0	2,70	2,00	2,5
0	4,55	5,26	4,55	5
−2,5	7,23	7,96	7,23	7,5
−5	10,05	10,80	10,05	10

Key: (1). Branching cf tha primary winding cf transformer, o/c. (2). Value of addition cf vcltage cr transformer, c/c. (3). Nominal voltage of secondary winding cf transformer, in. (4). Rounded value cf addition, o/o

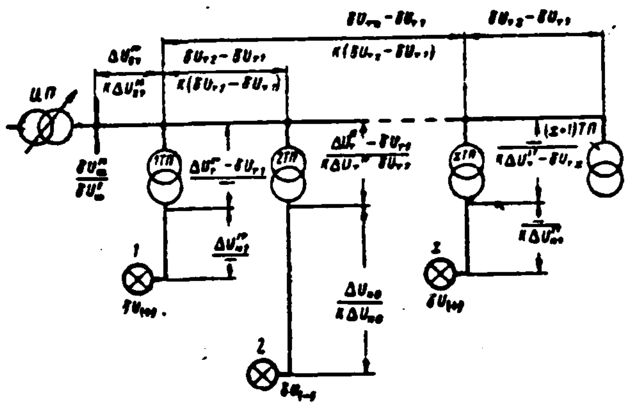

Fig. 11-3. Losses of line vcltage in the modes/conditions of maximum and minimum loads.

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1. Greatest voltage errcr cn busbars TsP during mode/conditicns of peak loads is limited tc conditicn that vcltage errcr on terminals/grippers of clcsest tc TsP electric receiver cn exceeds that permitted $\delta U_{(+)}$ (Fig. 11-3):

$$\delta U''_{ш} \leqslant \delta U_{(+)} + \Delta U''_{в1} + \Delta U''_{т} - \delta U_{т1} + \Delta U''_{н1}, \% \qquad (11\text{-}4)$$

where $\Delta U''_{в1}$ - loss of voltage in net 6-20 kV from TsP to nearest TP, o/o;

$\Delta U''_{т}$ - loss of voltage in transicrmer, o/o;

$\Delta U''_{н1}$ - loss of voltage from secondary side of distribution transformer to nearest electrical receiver, c/o;

$\delta U_{т1}$ - addition of voltage for branching +5c/c.

2. From diagram of voltages cn Fig. 11-2 it is evident that lowest voltage in mode/cenditicns of peak loads will be on terminals/grippers of receiver E_2, which obtains feed from

transformer 2, connected to network 6-20 kV at the end of zone of branching +5o/o. Voltage cn this receiver will remain within the limits of the permissitle witn the fulfillment condition (see Fig. 11-1 and 11-3)

$$\delta U''_{\text{ш}}-\delta U_{\text{з.в}}\geqslant\delta U_{(-)}+\Delta U''_{\text{н1}}+(\delta U_{\text{т2}}-\delta U_{\text{т1}})+$$
$$+\Delta U''_{\text{т}}-\delta U_{\text{т1}}+\Delta U_{\text{нн}},\ \%.$$

where $\delta U_{\text{т2}}$ - addition cr voltage with the branching of the winding of transformer +2.5, o/c.

Hence is determined the value of the permissible loss of line voltage to 1000 V:

$$\Delta U_{\text{нн}}\leqslant\delta U''_{\text{ш}}-\delta U_{\text{з.в}}-\delta U_{(-)}-\Delta U''_{\text{н1}}-$$
$$-\delta U_{\text{т2}}+2\delta U_{\text{т1}}-\Delta U''_{\text{т}},\ \%. \qquad (11\text{-}5)$$

3. Minimum deviaticn cr vcltage on tusbars of TsP in mode/conditions of minimum lcads is limited tc condition that voltage errcr on terminals/grippers cr electrical receiver E_2 does nct leave permissible limits (see Fig. 11-2 and 11-3):

$$\delta U'_{\text{ш}}\geqslant\delta U_{(-)}+K(\Delta U''_{\text{н1}}+\delta U_{\text{т2}}-\delta U_{\text{т1}}+$$
$$+\delta U''_{\text{т}}+\Delta U_{\text{нн}})-\delta U_{\text{т1}},\ \%. \qquad (11\text{-}6)$$

In the latter/last formula in the brackets is shown total loss of voltage from TsP to electrical receiver E_2 during the mode/conditions of peak loads, and coefficient K, determined according to formula (11-2), considers the decrease of the lcss of voltage indicated during the mcde/conditions cf minimum loads.

4. Number of branching x of latter/last zone is determined frcm condition that voltage error cn terminals/grippers cf electrical

receiver $A_{\text{х}}$ in mode/conditions of minimum loads does not exceed that permitted $\delta U_{(+)}$ (Fig. 11-2 and 11-3):

$$\delta U'_{\text{м}} \leqslant \delta U_{(+)} - \delta U_{\text{э.н}} + K(\Delta U''_{\text{в1}} + \delta U_{\text{т.х}} - \\ - \delta U_{\text{т1}} + \Delta U''_{\text{т}} + \Delta U''_{\text{в1}}) - \delta U_{\text{т.х}}, \%. \qquad (11\text{-}7)$$

where $\delta U_{\text{т.х}}$ - addition of voltage for branching x of winding of transformer, o/o.

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From this,

$$\delta U_{\text{т.х}} \leqslant \frac{\delta U_{(+)} - \delta U'_{\text{м}} - \delta U_{\text{э.н}} + K(\Delta U''_{\text{в1}} - \delta U_{\text{т1}} + \Delta U''_{\text{т}} + \Delta U''_{\text{в1}})}{1-K}, \%. \qquad (11\text{-}8)$$

On table 11-2 is selected the number of branching for which the addition it does not exceed the value, obtained according to formula (11-8).

After substituting the refined value of addition $\delta U_{\text{т.х}}$ into formula (11-7), we will obtain the upper limit of the standard deviations of voltage on the busbars of TsP in the mode/conditions of minimum loads $\delta U'_{\text{м.в}}$. The lower limit of this divergence $\delta U'_{\text{м.н}}$ was determined above according to formula (11-6).

Thus, in the mode/conditions of minimum loads voltage errors on the busbars of TsP must satisfy the condition

$$\delta U'_{\text{м.н}} \leqslant \delta U'_{\text{м}} \leqslant \delta U'_{\text{м.в}}, \%. \qquad (11\text{-}9)$$

5. Value of permissible loss of line voltage 6-20 kV is determined by end/lead of zone branchings x of winding of transformer (Fig. 11-3):

$$\Delta U_{\text{вс}} \leqslant \Delta U''_{\text{в1}} + \delta U_{\text{тх}} + \delta U_{\text{т2}} - 2\delta U_{\text{т1}},\ \%. \qquad (11\text{-}10)$$

6. Average values of voltages in modes/conditions of maximum and minimum loads can be determined respectively according to formulas (see Fig. 11-1):

$$\delta U''_{\text{у}} = \delta U''_{\text{м}} - 0{,}5\delta U_{\text{з.н.}}\ \%; \qquad (11\text{-}11)$$

$$\delta U'_{\text{у}} = \delta U'_{\text{м}} + 0{,}5\delta U_{\text{з.н.}}\ \%. \qquad (11\text{-}12)$$

Example to 11-1. To determine the range of regulating voltage into TsP and values of the permissible losses of voltage in urban distribution networks 380/220 V and 6-20 kV under the following conditions:

1. The load of network/grid is uniform and the graphs/curves of its changes with time for all connected to the network/grid 6-20 kV transformers are virtually identical.

2. Ratio of minimum summed current of transformer in TsP to maximum K=0.2.

3. Dead zone of device/equipment RPN in TsP $\delta U_{\text{з.н}} = 2{,}2\%$.

4. Standard deviations on terminals/grippers of receivers $\delta U_{(+)} = +5\%$ и $\delta U_{(-)} = -5\%$.

5. Losses of voltage in transformer for mode/conditions of peak loads $\Delta U''_{т}=3{,}5\%$.

6. Loss of voltage from busbars of TsP to nearest TP $\Delta U''_{н1}=0$.

7. Loss of voltage from busbars of distributing frame in TP to closest electrical receiver $\Delta U''_{н1}=0{,}5\%$.

Solution. Consecutively/serially they are determined from formulas (11-4), (11-5), (11-6) and (11-8):

$$\delta U''_{ш}=5+0+3{,}5-0{,}25+0{,}5=8{,}75\%;$$
$$\Delta U_{н0}=8{,}75-2{,}2-(-5)-0-2{,}7+2\cdot 0{,}25-3{,}5=5{,}85\%;$$
$$\delta U'_{ш}=\delta U'_{ш.з}=-5+0{,}2(0+2{,}7-0{,}25+3{,}5+5{,}85)-0{,}25=-2{,}89\%;$$
$$\delta U_{тр}\leqslant\frac{5-(-2{,}89)-2{,}2+0{,}2(0-0{,}25+3{,}5+0{,}5)}{1-0{,}2}=8{,}05\%.$$

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On Table 11-2 we select the branching of the winding of transformer -2.5o/o, for which the addition of voltage satisfies the condition

$$7{,}96<8{,}05\%.$$

The upper limit of the standard deviations of voltage on the busbars of TsP is determined from formula (11-7):

$$\delta U'_{ш.в}=5-2{,}2+0{,}2(0+7{,}96-0{,}25+3{,}5+0{,}5)-7{,}96=-2{,}82\%.$$

We accept in the conformity with formula (11-9) $\delta U'_{ш}=-2{,}85\%$.

According to formulas (11-10), (11-11) and (11-12) we determine

$$\Delta U_{\text{нв}}=0+7{,}96+2{,}7-2\cdot 0{,}25=10{,}16\%;$$
$$\delta U''_{\text{у}}=8{,}75-0{,}5\cdot 2{,}2=7{,}65\%;$$
$$\delta U'_{\text{у}}=-2{,}85+0{,}5\cdot 2{,}2=-1{,}75\%.$$

Example 11-2. Tc find tha sclution for the data of example by 11-1, but when distributicn networx of city cbtains feed through the busbars RP and closest tc TsP transformer substation is connected at the point of network/grid, the loss of vcltage cf up to which from the busbars of TsP comprises:

$$\Delta U''_{\text{в1}}=3{,}5\%.$$

Solution:

$$\delta U''_{\text{ш}}=5+3{,}5+3{,}5-0{,}25+0{,}5=12{,}25\%;$$
$$\Delta U_{\text{нв}}=12{,}25-2{,}2-(-5)-3{,}5-2{,}7+2\cdot 0{,}25-3{,}5=5{,}85\%;$$
$$\delta U'_{\text{ш.н}}=-5+0{,}2(3{,}5+2{,}7-0{,}25+3{,}5+5{,}85)-0{,}25=-2{,}19\%;$$
$$\delta U_{\text{тр}}\leqslant\frac{5-(-2{,}19)-2{,}2+0{,}2\,(3{,}5-0{,}25+3{,}5+0{,}5)}{1-0{,}2}=8{,}06\%;$$
$$\delta U'_{\text{ш.у}}=5-2{,}2+0{,}2(3{,}5+7{,}96-0{,}25+3{,}5+0{,}5)-7{,}96=-2{,}12\%;$$
$$\delta U'_{\text{ш}}=2{,}15\%;$$
$$\Delta U_{\text{вв}}=3{,}5+7{,}96+2{,}7-2\cdot 0{,}25=13{,}66\%;$$
$$\delta U''_{\text{у}}=12{,}25-0{,}5\cdot 2{,}2=11{,}15\%;$$
$$\delta U'_{\text{у}}=-2{,}15+0{,}5\cdot 2{,}2=-1{,}05\%.$$

11-3. Local regulating cf vcltage.

The contrary regulating cf vcltage in TsP cannct ensure the satisfactory quality cf vcltage fcr the group cf the receivers, the graph/curve of changes cf loads cf which in the time considerably differs from the graph/curve cf the total lcad of transformer in TsP.

In this case for obtaining the satisfactory mode/conditions of voltage is necessary the use of means of the local regulating of voltage.

In electrical networks where occurs the considerable consumption of reactive power, for regulating the voltage first of all must be used capacitor banks of transverse compensation (KB) and synchronous engines (SD), since in this case simultaneously is reached a considerable decrease in the losses of electrical energy in the network/grid.

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Use for the local regulating of voltage in such networks/grids of distribution transformers with RPN or the linear regulating autotransformers proves to be uneconomical.

Fig. 11-4 depicts the simplified circuit of distribution network to 1000 V, in which for local regulation of voltage are utilized source of reactive power (KB or SD), connected at point C. In this figure: A - nearest to transformer receiver of the electrical energy: B - the outermost receiver.

On the diagram of voltages (below in Fig. 11-4) point A_1

corresponds to smallest load voltage of the nearest receiver, and point A_2 - to the greatest voltage. The corresponding voltage errors on the terminals/grippers of receiver A without the account the additions of the voltage of transformer are designated by $\delta U_{A\,мин}$ and $\delta U_{A\,макс}$.

The reactive source power, sufficient for regulating the voltage, is determined from the formula

$$Q_p = \frac{10 U_н^2 \underset{*}{U} \delta U_A}{X_A}, \; квар, \qquad (11\text{-}13)$$

where $U_н$ - nominal voltage is net, kV:

$\underset{*}{U}$ - relative value of line voltage at the point of the connection of the source of the reactive power;

X_A - the reactance of external network/grid with respect to the attachment point of nearest receiver, ohm;

δU_A - range of regulating the voltage:

$$\delta U_A = \delta U_{A\,макс} - \delta U_{A\,мин}. \qquad (11\text{-}14)$$

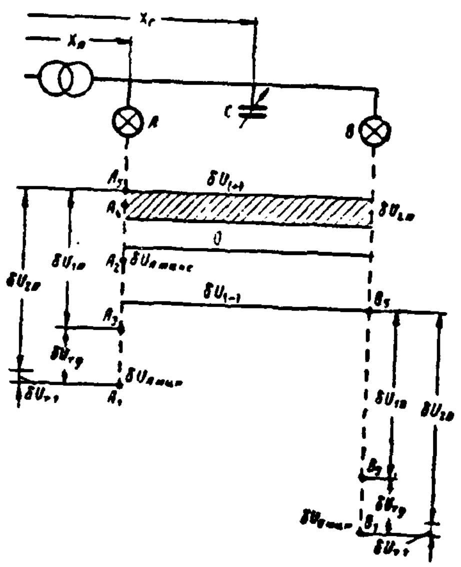

Fig. 11-4. Diagram for the selection of the range of the local regulating of voltage.

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Total reactive source power depends on the selected branching of transformer. Largest and smallest of its value are determined respectively according to the formulas:

$$Q_{макс} = \frac{\delta U_{2A}}{\delta U_A} Q_р, \text{ квар}^{(1)}; \qquad (11\text{-}15)$$

$$Q_{мин} = \frac{\delta U_{1A}}{\delta U_A} Q_р, \text{ квар}^{(1)}. \qquad (11\text{-}16)$$

Key: (1). kilovar.

From the diagram cn BS 11-4 it follcws:

$$\delta U_{2A}=\delta U_{(+)}-\delta U_{A\,\text{макс}}-\delta U_{T1},\ \%; \quad (11\text{-}17)$$

$$\delta U_{1A}=\delta U_{(+)}-\delta U_{A\,\text{мин}}-\delta U_{TT},\ \%. \quad (11\text{-}18)$$

where δU_{T1} - addition of tne vcltage of transformer with branching +5c/o, o/o;

δU_{TT} - addition of the vcltage ci transfcrmer, determined on Table 11-2 in depending cn the ccndition

$$U_{TT}\leqslant\delta U_{(+)}-\delta U_{A\,\text{макс}},\ \%. \quad (11\text{-}19)$$

With the realizaticn of the lccal regulating of voltage the value of the permissible lcss oi line voltage is determined frcm the condition

$$\Delta U_{\text{вл}}\leqslant\delta U_{(+)}-\delta U_{\text{з.в}}+\delta U_{(C-A)}-\delta U_{(-)},\ \%. \quad (11\text{-}20)$$

where $\delta U_{(C-A)}$ is calculated in depending cn the branching of transformer accepted frcm cne cf the formulas

$$\delta U_{(C-A)}=\left(\frac{X_C}{X_A}-1\right)\delta U_{2A},\ \%; \quad (11\text{-}21)$$

$$\delta U_{(C-A)}=\left(\frac{X_C}{X_A}-1\right)\delta U_{1A},\ \%. \quad (11\text{-}22)$$

In these formulas X_C - tne reactance of external network/grid in the ohms with respect tc tne attachment point cf the source cf reactive power, utilized for tne regulating vcltage.

If for regulating tha vcltage is utilized KB, then its ncminal power is determined frcm tc the fcrmula

$$Q_{\kappa} = \frac{Q}{U^2}, \; ^{(1)}_{\kappa sap},\qquad (11\text{-}23)$$

Key: (1). kilovar.

where Q - the calculated reactive power of KB, obtained on one of formulas (11-15) or (11-16) by the kilovar;

U - relative value of line voltage at the point of the connection of KB.

KB is recommended to divide in the section of the equal power whose number in depending on concrete/specific/actual conditions can be accepted as different.

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During the use of KB for regulating the voltage in the lighting systems it is necessary to check, do satisfy the value of degree of regulating and the frequency or the inclusions of sections of KB requirements of GOST 13109-67 for the quality of voltage (Table 5-11).

When selecting of reactive source power, utilized as the means of regulating voltage, it is necessary to keep in mind that generated by this source the reactive power must not considerably exceed the consumed in the network/grid reactive power. Use for regulating the

voltage of KB or SD in electrical networks in which the power factor is close to the unit, can prove to be economically unsuitable.

For the tentative calculations when selecting of power of KB Table 11-3 gives to the step/stage of regulating upon the inclusion/connection of section of KB with a power of 100 kilovar when the reactance of external network/grid is equal to the resistor/resistance of the indicated in the table element/cell.

Example 11-3. Electric motors and lighting fixtures of the shop of industrial enterprise are connected to general/common/total distribution network by 380/220 V and obtain feed from transformer with a power of 1000 kVA, 10/0.4/0.23 kV. The greatest consumed reactive power of shop is equal to 920 kilovars. The standard deviations of load voltage of lighting fixtures are equal to $\delta U_{(+)}=+5\%$ and $\delta U_{(-)}=-2.5\%$ (according to GOST 13109-67).

On the terminals/grippers of the nearest to the transformer lighting fixture the voltage errors (without the account the additions of the voltage of transformer) can vary in the range from $\delta U_{A\,\text{мин}}=-7\%$ to $\delta U_{A\,\text{макс}}=-1.5\%$.

Table 11-3. Steps/stages of regulating voltage upon the inclusion/connection of KB.

(1) Наименование элемента внешней сети	(2) Ступень регулирования напряжения для КВ мощностью 100 квар, %	(3) Мощность секции КВ, при которой ступень регулирования равна 1%, квар
(4) Трансформатор 6—10/0,4 кв мощностью, ква		
100	5,5	18
160	3,5	29
250	2,3	43
400	1,45	70
630	0,9	110
1 000	0,59	170
(5) Воздушная линия длиной 1 км на номинальное напряжение, кв		
0,38	21	4,8
6	1,05	95
10	0,038	2 600
20	0,01	10 000
(6) То же кабельная линия, кв		
0,38	4,15	24
6	0,022	4 500
10	0,008	12 500
20	0,00275	36 300

Key: (1). Designation of the element/cell of external network/grid. (2). Step/stage of regulation of voltage for KB in power 100 kilovar, o/o. (3). Power of section KB, at which step/stage of regulating is equal to 1o/o, kilovar. (4). Transformer 6-10/04 kV by power, kVA. (5). Aerial line with a length of 1 km nominal voltage, kV. (6). Then cable line, kV.

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To determine power of KB, utilized for the regulating of voltage in the network/grid of shop, and the value of the permissible loss of

voltage in this network/grid under the following conditions:

the reactance of external network/grid is equal respectively:

to nearest lighting fixture $X_{\text{л}}=0{,}01$ Ω

to the point of the connection of KE $X_c=0{,}014$ Ω.

Relative value of line voltage at the point of the connection of KB $\underset{*}{U}=1$.

The amount of power or KB must be approximately/exemplarily equal to the maximum value of the consumed reactive power.

Solution. We determine the necessary range of regulating voltage according to formula (11-14):

$$\delta U_{\text{л}}=-1{,}5-(-7)=5{,}5\%.$$

Corresponding to this power range of KB we find through formula (11-13):

$$Q_p=\frac{10\cdot 0{,}38^2\cdot 1\cdot 5{,}5}{0{,}01}=792 \overset{(1)}{\text{квар.}}$$

Key: (1). kilovar.

For determining the smallest total power of KB from Table 11-2 we select branching of the windings of shop transformer in depending

on the value of the addition of voltage, determined from condition (11-19):

$$\delta U_{\tau\pi} \leqslant 5-(-1.5)=6.5\%.$$

We accept the fundamental branching of the transformer for which $\delta U_{\tau\pi}=5.26\%$.

Power of KB we determine from formulas (11:18) and (11:16):

$$\delta U_{1A}=5-(-7)-5.26=6.74\%;$$

$$Q_{мин}=\frac{6.74}{5.5}\cdot 792=970 \overset{(1)}{квар}.$$

Key: (1). kilovar.

We accept the power of one section of KB of the equal to 160 kilovars and the total number of sections equal to 6. In this case the power of KB will be equal to:

$$Q=Q_{в}=6\cdot 160=960 \text{ kilovar}.$$

Of six sections of KB one must remain connected round-the-clock, and the others must be used for regulating the voltage.

The power of KB accepted satisfies that set the example to the condition for the complete compensation for the consumed in the shop reactive power.

Upon the inclusion of one section of KB at point C and at all

more distant points of network/grid the value of the oscillations/vibrations of voltage will be equal to:

$$\delta U_1 = \frac{0.014}{0.01} \cdot \frac{6 \cdot 74}{6} = 1.57\ \%.$$

On Table 5-11 we determine that the frequency of inclusions and cutoffs/disconnections of sections of KB into the hour according to effect condition of the oscillations/vibrations of voltage on the work of lighting fixtures must not exceed 10.

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The dead zone of controlling device can be accepted equal to:

$$\delta U_{з.н} = 1{,}57 + 0{,}6 \approx 2{,}2\%.$$

The value of the permissible loss of line voltage of shop we determine from formulas (11-22) and (11-20)

$$\delta U_{(C-Л)} = \left(\frac{0.014}{0.01} - 1\right) \cdot 6.74 = 2.7\ \%;$$

$$\Delta U_{н0} = 5 - 2{,}2 + 2{,}7 - (-2{,}5) = 8\%.$$

11-4. Selection of the sources of reactive power according to the condition of efficiency/cost-effectiveness.

The selection of the sources of reactive power and points/items of their connections by the design must be conducted on the minimum of total expenditures taking into account the cost/value of generation and transmission of reactive power to the place of use.

Fig. 11-5 depicts the case when into point/item A of network/grid reactive power can be transmitted from the n sources. Compensation consumed in point A or reactive power Q_A can be also realized by means of connection in this point/item of capacitor bank C.

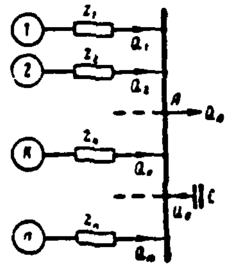

Fig. 11-5. Diagram of tne kalance cf reactive power for the ncde of network.

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In this case the tctal quantity of expenditures fcr generaticn and transmission of reactive pcwer can be determined according to the fcrmula

$$З = \sum_{k=0}^{n} (З_{0k} + З_{1k}Q_k + З_{2k}Q_k^2),\ руб. \qquad (11\text{-}24)$$

where Q_k - the reactive power, generated by scurce k, Mvar;

$З_{0k}$, $З_{1k}$ and $З_{2k}$ - values, determined for the grcup of generatcrs or synchronous motors acccrding tc the formulas:

$$\left.\begin{aligned} З_{0k} &= \Sigma p_a K_k,\ руб^{(1)};\\ З_{1k} &= \frac{\gamma_k b_1 m (D_1 + 2D_2\psi) T}{Q_k} + b_1 C_1 T,\ руб/Мвар^{(2)};\\ З_{2k} &= \frac{\gamma_k^2 b_2 m D_2 \tau}{Q_k^2} + b_2 C_2 \tau,\ руб/Мвар^2 \end{aligned}\right\} \qquad (11\text{-}25)$$

Key: (1). rub. (2). rub/Mvar.

and for capacitor banks cf transverse compensaticn according to the formulas:

$$\left.\begin{aligned} З_{0к} &= \Sigma p_0 K_0, \text{ руб.}; \text{ (1)} \\ З_{1к} &= \gamma_к (p_1 K_1 + b_1 fT) + b_1 C_1 T, \text{ руб/Мвар}; \text{ (2)} \\ З_{2к} &= b_2 C_2 \tau, \text{ руб/Мвар}^2. \text{ (2)} \end{aligned}\right\} \quad (11\text{-}26)$$

Key: (1). rub. (2). rub/Mvar.

In formulas (11-25) and (11-26):

K_0 - capital investments in the equipment of the scurce cf the reactive power, which dc not depend on the amcunt of the generatable and transmitted by the network/grid power, rub; for example, for condenser/capacitcr bank (KB) of 6-10 kV these insertions are composed of the cost/value cf chamber/camera KU to the commutating apparatus and cable fcr the ccnnections cf KB tc the busbars, the cost/value of the building of substation (if installaticn of KB requires expansion of substaticn) and of the like;

K_1 - specific capital investments, in reference to 1 Mvar of the generated by source reactive power, rub/Mvar;

p_0 and p_1 - total annual deductions respectively from capital investment K_0 and K_1. the switching on cceefficient effectivenesses,

deduction to the renovation, the major overhaul and the maintenance/servicing;

T - annual total hours of utilization the generated by source reactive power;

τ - annual number of hours of the maximum losses;

Q_n - total rated power of the group of synchronous machines, Mvar;

m - number of the synchronous machines;

f - loss tangent of capacitors/condensers, MW/Mvar;

D_1 and D_2 - coefficients, which depend on technical specifications of machines, Mw.

Fundamental technical specifications of the most widely used synchronous motors are given in Table 11-4, and the corresponding to them coefficients D_1 and D_2 - in Table 11-5.

Coefficient φ characterizes the relative charging of the reactive power of the synchronous machines

$$\varphi = \frac{Q'}{Q_n}, \tag{11-27}$$

where $Q_н$ - total nominal reactive/jet power of machines, Mvar;

Q' - generated by machines reactive power without the account to the power, transmitted to point A of network/grid, Mvar.

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The components/terms/addends b_1C_1T and $b_2C_2\tau$ in formulas (11-25) and (11-26) determine the cost/value of the losses of electrical energy in the network/grid during the transmission of reactive power from the source to the place of consumption. The specific costs/values of losses b_1 and b_2 are determined from formula (10-13) for an annual number of hours with respect to T and τ.

Coefficient $\gamma_н$ considers an increase in the generated by source reactive power due to the losses in the network/grid during its transmission to the place of the consumption:

$$\gamma_{н1}=1+E_1+E_2Q_н. \quad (11\text{-}28)$$

Coefficients C_1 and C_2 in formulas (11-25) and (11.26) and coefficients E_1 and E_2 in formula (11-28) depend on the parameters of the network/grid between the source of reactive power and the point/item of its consumption.

Table 11-4. Fundamental technical specifications of synchronous motors 6-10 kV.

(1) Тип двигателя	(2) Номинальное напряжение, кв	(3) Номинальная мощность			(7) Скорость вращения, об/мин	(8) Номинальные потери активной мощности, квт	(9) к. п. д., %
		(4) полная, ква	(5) активная, квт	(6) реактивная, квар			
СДН 14-49-6	6	1 170	1 000	510	1 000	53	95.2
СДН 15-39-6	6	1 860	1 600	811	1 000	74	95.7
СДН 16-69-6	6	4 600	4 000	2 005	1 000	140	96.7
СДН 16-104-6	6	7 220	6 300	3 147	1 000	198	97.1
СДН 17-119-8	6	11 420	10 000	4 978	750	278	97.3
СДН 18-71-12	6	7 250	6 300	3 160	500	225	96.7
СДН 18-111-12	6	11 700	10 000	4 991	500	305	97.4
СДН 19-54-24	6	4 650	4 000	2 027	250	185	95.6
СДН 18-14-40	6	415	320	181	150	53.5	85.5
СДН 18-24-40	6	615	500	263	150	53.5	90.8
СДН 19-31-60	6	985	800	429	100	86.5	90.4
СДН 20-31-60	6	1 920	1 600	837	100	128	92.4
ВДС 213/24-10	6	1 520	1 300	663	600	68	95.0
СДС 16-41-20	6	955	800	416	300	59.5	93.6
СДК 18-16-36	6	495	400	216	167	45.5	90.0
СТМ 1500-2	6	1 750	1 500	763	3 000	75	95.4
СТМ 3500-2	6	4 050	3 500	1 765	3 000	145	96.2
СТМ 12000-2	6	13 700	12 000	5 972	3 000	330	97.5
СДСЗ 19-125-16	6	22 400	19 500	—	375	—	96.7
МС 325-20/12	10	11 700	9 000	7 500	500	1 530	85.5
МС 213-15/8	10	6 500	5 000	3 900	750	200	96.4
ДСЗ 1811-6	10	3 000	2 580	1 307	1 000	120	95.6
СДНЗ 15-49-10	10	1 460	1 250	636	600	64	95.3
СДН 16-71-10	10	1 880	1 600	820	600	92	94.7
СДСЗ 17-10-6	10	1 600	1 230	960	1 000	50	96.2
СДСЗ 290-12-16	10	4 900	4 200	2 136	375	210	95.4
СДСЗ 19-125-16	10	20 000	18 500	—	375	—	97.4

Key: (1). Type of engine. (2). Nominal voltage, kV. (3). Rated power. (4). complete, kVA. (5). active, kw. (6). reactive/jet, kilovar. (7). Speed of rotation, r/min. (8). Rated losses by active power, kW. (9). Efficiencies.

Page 256. Table 11-5. The available reactive power and the value of coefficients in formula (11-25) for the synchronous motors 6-10 kV in depending on load voltage and the load factor.

(1) Тип двигателя	(2) Располагаемая реактивная мощность двигателя при напряжении на зажимах, %									(3) Значения коэффициентов в формуле (11-25), квт	
	95			100			105			D_1	D_2
	(4) Коэффициент загрузки двигателя										
	0.6	0.8	1	0.6	0.8	1	0.6	0.8	1		
СДН 14-49-6	1.53	1.43	1	1.36	1.29	1	1.15	1.08	1	6.3	3.84
СДН 15-39-6	1.47	1.35	1	1.35	1.26	1	1.21	1.12	1	8.42	5.28
СДН 16-69-6	1.41	1.25	1	1.32	1.23	1	1.16	1.12	1	15.7	11.0
СДН 16-101-6	1.45	1.31	1	1.32	1.25	1	1.12	1.09	1	18.8	12.5
СДН 17-119-8	1.47	1.35	1	1.33	1.26	1	1.10	1.07	1	28.3	19.7
СДН 18-71-12	1.45	1.33	1	1.31	1.25	1	1.09	1.07	1	27.1	16.5
СДН 18-111-12	1.55	1.45	1	1.37	1.30	1	1.14	1.08	1	30.6	20.8
СДН 19-51-21	1.41	1.28	1	1.27	1.23	1	1.07	1.07	1	24.4	23.4
СДН 18-11-10	1.44	1.37	1	1.30	1.24	1	1.12	1.08	1	7.13	4.71
СДН 18-21-40	1.18	1.40	1	1.32	1.26	1	1.13	1.08	1	8.7	6.4
СДН 19-31-60	1.47	1.39	1	1.31	1.25	1	1.06	1.05	1	14.2	11.8
СДН 20-31-60	1.57	1.51	1	1.35	1.30	1	1.09	1.06	1	22.3	12.9
ВДС 213/24-10	1.47	1.28	1	1.42	1.29	1	1.33	1.22	1	7.62	6.93
СДС 16-41-20	1.53	1.45	1	1.33	1.28	1	1.10	1.06	1	7.2	5.95
СДК 18-16-36	1.52	1.46	1	1.33	1.28	1	1.12	1.07	1	5.78	5.0
СТМ 1500-2	1.57	1.38	1	1.50	1.32	1	1.41	1.24	1	5.85	7.26
СТМ 3500-2	1.56	1.35	1	1.51	1.32	1	1.43	1.26	1	8.88	12.6
СТМ 12000-2	1.57	1.34	1	1.54	1.33	1	1.18	1.28	1	29.6	43.2
СДСЗ 19-125-16	1.50	1.40	1	1.35	1.27	1	1.17	1.10	1	57.3	29.3
МС 325-20/12	1.80	1.59	1	1.47	1.43	1	1.07	1.04	1	78.7	37.0
МС 213-15/8	1.26	1.21	1	1.16	1.14	1	1.01	1.01	1	23.6	23.6
ДСЗ 1811-6	1.57	1.42	1	1.46	1.32	1	1.29	1.17	1	12.0	4.92
СДНЗ 15-49-10	1.48	1.37	1	1.35	1.26	1	1.20	1.11	1	6.98	4.42
СДН 16-71-10	1.70	1.59	1	1.43	1.38	1	1.11	1.06	1	8.55	6.63
СДСЗ 17-10-6	1.35	1.27	1	1.27	1.19	1	1.15	1.09	1	5.9	8.3
СДСЗ 200-12-16	1.65	1.57	1	1.40	1.35	1	1.11	1.06	1	18.9	14.7
СДСЗ 19-125-16	1.89	1.75	1	1.52	1.42	1	1.17	1.10	1	35.5	19.7

Key: (1). Type of engine. (2). Available reactive power of engine with load voltage. (3). Values of coefficients in formula (11-25), KVM. (4). Load factor of engine.

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Upon the connection of electrical devices of low and average/mean power to the networks/grids of powerful/thick power systems the values of these coefficients can be determined from the approximation

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formulas:

$$\left.\begin{aligned} C_1 &= \frac{2\sum_{i=0}^{n-1} Q_{i,\,i+1}R_{i,\,i+1}}{U_н^2};\\ C_2 &= \frac{\sum_{i=0}^{n-1} R_{i,\,i+1}}{U_н^2}; \end{aligned}\right\} \quad (11\text{-}29)$$

$$\left.\begin{aligned} E_1 &= \frac{2\sum_{i=0}^{n-1} Q_{i,\,i+1}X_{i,\,i+1}}{U_н^2};\\ E_2 &= \frac{\sum_{i=0}^{n-1} X_{i,\,i+1}}{U_н^2}. \end{aligned}\right\} \quad (11\text{-}30)$$

where $U_н$ - nominal voltage cf netwcrk/grid, kV;

$Q_{i,i+1}$ - reactive/jet power in the section $i-(i+1)$ without the account to reactive power, required in ncde A (Fig. 11-6), Mvar;

$R_{i,i+1}$ and $X_{i,i+1}$ - respectively active and reactance of section $i-(i+1)$, led to voltage $U_н$, ohm.

If source is connected directly to the place of the consumpticn of reactive power (fcr example, ccndenser/capacitor bank C in Fig. 11-5), then expenditures for its transmissicn are equal to zero and coefficient $\gamma_н$ should be taken as equal to 1. Fcr this case cf the amcunt of the reactive pcwer, transmitted frcm each source tc the

point/item of the consumptions, which correspond to the minimum of expenditures, they are determined from the formulas:

$$\left.\begin{aligned} Q_{\kappa} &= \frac{З_{1o} - З_{1\kappa}}{2З_{2\kappa}}; \ \kappa = 1, 2, \ldots, n; \\ Q_{o} &= Q_{p} - \sum_{k=1}^{n} Q_{k}. \end{aligned}\right\} \qquad (11\text{-}31)$$

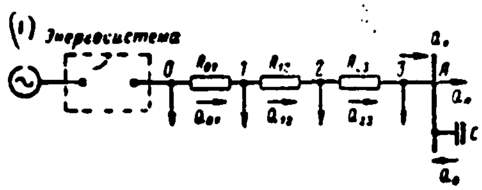

Fig. 11-6. Replacement scheme of radial network/grid.

Key: (1). power system.

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If according to the technical or economic specifications of KB it cannot be established/installed in the point/item of the consumption (battery C in Fig. 11-5 is absent), then the optimum amounts of reactive source power are determined from the formulas

$$\left.\begin{aligned} \lambda &= \frac{2Q_A + \sum\limits_{k=1}^{n} \frac{З_{1к}}{З_{2к}}}{\sum\limits_{k=1}^{n} \frac{1}{З_{2к}}}; \\ Q_к &= \frac{\lambda - З_{1к}}{2З_{2к}}; \; к = 1, 2, \ldots n. \end{aligned}\right\} \quad (11\text{-}32)$$

To the amount of generatable and transmitted to the point/item of consumption reactive power are superimposed the limitations according to the conditions of the thermal conditions of stator-rotors unit of machines $Q_{к.макс}$ and the stability condition of their work $Q_{к.мин}$:

$$Q_{к.макс} \geqslant Q_к \geqslant Q_{к.мин} \quad (11\text{-}33)$$

also, for capacitor banks with respect to the condition

$$Q_{\text{к}} \geqslant 0. \qquad (11\text{-}34)$$

Furthermore, must be checked fulfilling technical requirements for the values of voltage at all points and the currents in all elements/cells of network/grid.

The greatest permissible amount of generated by engine reactive power $Q_{\text{к.макс}}$ can be determined in depending on the load factor of engine and value of voltage on its terminals/grippers in Table 11-5.

Technical specifications of capacitors/condensers are given to Table 11-6, cost/value of ganged condenser/capacitor devices of the Ust'-Kamenogorsk condenser/capacitor plant - in Table 10-14 and values of dielectric loss factor - in Table 11-7.

If on the terminals/grippers of KB voltage differs from nominal, then the measure of its specific cost, determined on Table 10-14, must be refined according to the formula

$$K_1 = \frac{K_{1\text{н}}}{U^2}, \text{ rub/Mvar}, \qquad (11\text{-}35).$$

where $K_{1\text{н}}$ - specific cost/value of KB with the nominal voltage,

rub/Mvar;

U - relative value of line voltage at the point of the connection of KB.

With performing of calculations the values of coefficients are assigned on the basis of the experience of design engineer. Subsequently these values can be refined according to formulas (11-28) and (11-30).

Example 11-4. Industrial enterprise obtains electrical power from power system Э along the line 110 kV AE (Fig. 11-7a). Distributive point D, located in the shop of enterprise, is connected to the busbars 10 kV of substation 110/10 kV by the cable lines CD.

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The consumed in the shop reactive power in the mode/conditions of maximum composes Q_A=5 Mvar. As the sources of reactive power they can be used:

1) the generators of the power system;

2) synchronous motors of the type SDN-16-71-10 in power 1600 kW,

connected to the busbars БР or shop (number of engines m=7);

3) condenser/capacitor bank (КБ), connected up busbars the same БР (number of sections of КБ is accepted equal to two).

Table 11-6. Fundamental tecnnical specificaticns of capacitors/condensers fcr the transverse compensaticn.

(1) Тип конденсатора	(2) Номинальное напряжение, кв	(3) Номинальная мощность, квар	(4) Завод-изготовитель
КМ1-0,22	0,22	4—6	(5) Усть-Каменогорский конденсаторный завод
КМ1-0,38	0,38	13	
КМ1-0,5	0,5	13	
КМ2-0,22	0,22	10—12	
КМ2-0,38	0,38	25	
КМ2-0,5	0,5	25	
КМН2-1,05	1,05	25	
КМ1-1,05	1,05	14	
КМ2-1,05	1,05	25,5	
КМ1-3,15	3,15	13	
КМ1-6,3	6,3	12,5	
КМ1-10,5	10,5	15	
КМ2-3,15	3,15	27,5	
КМ2-6,3	6,3	28	
КМ2-10,5	10,5	27	
КМ2-0,22	0,22	8,35	Серпуховский завод „Конденсатор" (6)
КМ2-0,38	0,38	25	
КМ2-0,5	0,5	25	
КМ-0,6	0,6	9,5	
КМ-0,91	0,91	9,5	
КМ-1,05	1,05	10	
КМ-3,15	3,15	10	
КМ-6,3	6,3	10	
КМ-10,5	10,5	10	
КМ2-0,6	0,6	25	
КМ2-1,05	1,05	25	
КМ2-3,15	3,15	25	
КМ2-6,3	6,3	25	
КМ2-10,5	10,5	22,5	

Key: (1). Type of capacitcr/ccndenser. (2). Ncminal voltage, kV. (3). Nominal pcwer of kilcvar. (4). Manufacturing plant. (5). Ust'-Kamenogorsk condenser/capacitcr plant. (6). Serpukhov plant "Kcndensatcr".

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To determine the cptimum degree of utilizaticn of the scurces cf

reactive power indicated under the following conditions:

Synchronous motors are utilized exclusively for purposes of the compensation for reactive power in point/item D (value of coefficient $\nu=0$).

Cost indices:

chamber/camera KRU and cable for the connection of KB taking into account the installation works - 2000 rub;

regulator of the excitation of synchronous motor with the mounting - 500 rub;

regulator for the control of sections of KB with the mounting - 400 rub.

Specific expenditures, caused by the expansion of power plants for the compensation for power losses, α=24170 rub/MW.

Prime cost of the consumption/production/generation of electrical energy, switching on expenditures for the expansion of the fuel resources, β=4.96 rub/MW•h.

Coefficient of participation in the maximum of power system $K_m=1$.

Coefficient, which considers an increase in the cost/value of electric power for nets of industrial enterprise, б=1.2.

Annual total hours of utilization of a maximum of reactive power T=6000.

Number of hours of maximum losses τ=4600.

The amounts of the consumed reactive power in points/items C and D and the values of the resistors/resistances of the elements/cells of network/grid with respect to voltage 10 kV are shown in Fig. 11-7b.

Problem can be solved without the account to the cost/value of the generation of reactive power on the power plants of system and its transmission on the networks/grids of power system.

Table 11-7. Values of the loss tangent of capacitors/condensers.

(1) Завод-изготовитель	(2) Номинальное напряжение, кв	(3) Величина тангенса угла потерь (4) обычное исполнение	(5) экспортное и тропическое исполнения
(6) Серпуховский завод „Конденсатор"	<1,05 =1,05 >1,05	0,0045 0,0035 0,003	0,0035 0,003 0,0025
(7) Усть-Каменогорский конденсаторный завод	≤1,05 >1,05	0,0045 0,0035	

Key: (1). Manufacturer. (2). Nominal voltage, kV. (3). Value of loss tangent. (4). usual performance. (5). export and tropical performances. (6). Serpukhov plant "Kondensator". (7). Ust'-Kamenogorsk condenser/capacitor plant.

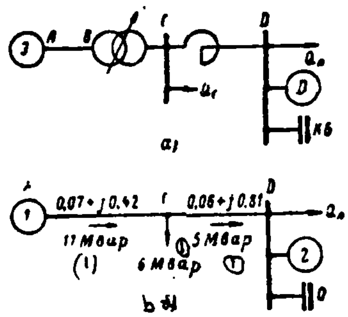

Fig. 11-7. Diagram for example 11-4.

Key: (1). Mbars.

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Solution. We determine the measures of the specific costs of the

losses of electrical energy according to formula (10-13)[1] for an annual number of hours with respect 6000 and 4600:

$$b_1 = 1.2\left(\frac{1 \cdot 24\,170}{6\,000} + 4.69\right) = 10.45 \text{ руб/Мвт·ч}; \ (1)$$

$$b_2 = 1.2\left(\frac{1 \cdot 24\,170}{4\,600} + 4.69\right) = 11.9 \text{ руб/Мвт·ч}. \ (1)$$

Key: (1). rub/MW•h.

FOOTNOTE [1]. In formula (10-13) to designations b_1 and b_2 corresponds γ. ENDFOOTNOTE.

Through Table 11-4 and 11-5 we find for the synchronous motor of the type SDN-16-71-10 of the amount of nominal reactive power - 0.82 Mvar and coefficients of D_1=8.55•10^{-3} MW and D_2=6.63•10^{-3} MW.

On Table 10-14 we select the sections of KB of the type KU 10-II of the Ust'-Kamenogorsk condenser/capacitor plant, for which specific cost/value composes 7100 rub/Mvar. The loss tangent for these capacitors/condensers is determined on tables 11-7; f=0.0035 MW/Mvar.

The values of yearly deductions from the capital investments we find from table 10-2: for the adjusters - 0.2492, for capacitor banks - 0.2222.

The components of expenditures for KB we determine from formulas (11-26), bearing in mind that it is connected directly in point D and, therefore, should be taken as γ_0 equal to one, and latter/last member in the second formula equal to zero:

$$З_{00}=2\cdot0{,}2222\cdot2\,000+0{,}2492\cdot400=988 \text{ руб.}; \ (1)$$
$$З_{10}=1\,(0{,}2222\cdot7\,100+10{,}45\cdot0{,}0035\cdot6\,000)+0=1\,800 \text{ руб/Мвар}; \ (2)$$
$$З_{20}=0.$$

Key: (1). rub. (2). rub/Mvar.

The components of the expenditures during the transmission of reactive power of the system we determine from formulas (11-25), in which the first terms must mode of life they are accepted equal bullet, since the cost/value of generation of reactive power on the power plants of system according to the condition of an example is not considered. The values of coefficients C_1 and C_2 are determined from formulas (11-29) taking into account the diagram in Fig. 11-7b:

$$C_1=\frac{2\,(11\cdot0{,}07+5\cdot0{,}06)}{10^3}=2{,}14\cdot10^{-3};$$

$$C_2=\frac{0{,}07+0{,}06}{10^3}=0{,}13\cdot10^{-3}.$$

Hence:

$$З_{01}=0;$$
$$З_{11}=10{,}45\cdot2{,}14\cdot10^{-3}\cdot6\,000=1\,340 \text{ руб/Мвар}; \ (1)$$
$$З_{21}=11{,}9\cdot0{,}13\cdot10^{-3}\cdot4\,600=71{,}3 \text{ руб/Мвар}^2. \ (2)$$

Key: (1). rub/Mvar. (2). rub/Mvar².

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The components of expenditures for the engines are determined on

formulas (11-25), in which is considered the cost/value of the generation of reactive/jet power (cost/value of the losses of electrical energy in the engines), and the cost/value of its transmission takes as equal to zero, since engines are connected directly in point D:

$$З_{02}=7\cdot 0{,}2492\cdot 500=872\ \text{руб.};\ (1)$$

$$З_{12}=\frac{1\cdot 10{,}45\cdot 7\,(8{,}55\cdot 10^{-3}+0)\cdot 6\,000}{7\cdot 0{,}82}+0=655\ \text{руб/Мвар};\ (2)$$

$$З_{22}=\frac{1\cdot 11{,}9\cdot 7\cdot 6{,}63\cdot 10^{-3}\cdot 4\,600}{(7\cdot 0{,}82)^2}+0=77\ \text{руб/Мвар}.\ (2)$$

Key: (1). rub. (2). rub/Mvar.

We determine from formulas (11-31) the optimum amounts of the reactive power, generated by each source:

for the generators of the power system

$$Q_1=\frac{1\,800-1\,340}{2\cdot 71{,}3}=3{,}27\ \text{Mvar};$$

for synchronous engines

$$Q_2=\frac{1\,800-655}{2\cdot 77}=7{,}45\ \text{Mvar}.$$

and for capacitor bank

$$Q_0 = 5 - 3{,}27 - 7{,}45 = -5{,}72 \text{ Mvar.}$$

For capacitor bank was obtained negative power and to establish/install it proves to be economically disadvantageously.

Remain two sources of reactive power, for which the calculation should be repeated according to formulas (11-32):

It is determined value λ:

$$\lambda = \frac{2 \cdot 5 + \frac{1\,340}{71{,}3} + \frac{655}{77}}{\frac{1}{71{,}3} + \frac{1}{77}} = 1\,380 \overset{(1)}{\text{руб/Мвар}}.$$

Key: (1). rub/Mvar.

Hence we determine the reactive power, transmitted from the system:

$$Q_1 = \frac{1\,380 - 1\,340}{2 \cdot 71{,}3} = 0{,}28 \text{ Mvar.}$$

and generated by the synchronous motors:

$$Q_2 = \frac{1\,380 - 655}{2 \cdot 77} = 4{,}72 \text{ Mvar.}$$

Thus, most economical source of reactive power in this case are synchronous engines. The minimum value of expenditures we determine

from formula (11-24):

$$З_{\text{мин}}=0+1\,340\cdot 0{,}28+71{,}3\cdot 0{,}28^2+872+655\cdot 4{,}72+$$
$$+77{,}4\cdot 4{,}72^2=6\,060\ \text{руб.}$$

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During the complete compensation for reactive power by the synchronous motors

$$Q_1=0;$$
$$Q_2=5\ \text{Мвар}\ (1)$$

Key: (1). Mvar.

and the values of expenditures will be equal to:

$$З=872+655\cdot 5+77{,}5^2=6\,070\ \text{rub.}$$

We verify for the engines satisfaction of condition (11-33).

Nominal reactive power of seven engines is equal to:

$$Q_н=7\cdot 0{,}82=5{,}75\ \text{MVA.}$$

As it follows from Table 11-5, this power can be provided with the full load of engines and changes in load voltage within the limits of 0.95-1.05 nominal ones. Under such conditions it is possible to accept:

$$Q_{\text{макс}}=5{,}75 \text{ Mvar.}$$

The stability of the work of engine with normally mode/conditions and cos ϕ=1 is provided, and it is possible to accept:

$$Q_{\text{мин}}\leqslant 0.$$

Since during the use of an engine for the compensation the generatable power can vary within the range of 0 to 5 Mvar, the condition (4-33) is satisfied:

$$5{,}75>Q_{\text{дв}}\geqslant 0.$$

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